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MODERN FIRE FIGHTING EQUIPMENT—A MEMBER OF NEW YORK'S RESCUE SQUAD SHUTTING DOWN A REFRIGERATING PLANT IN A CELLAR FILLED WITH ESCAPING AMMONIA FUMES (SEE PAGE 329)

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THE SINGING PIPE ORGAN

REGULAR readers of the SCIENTIFIC AMERICAN MONTHLY undoubtedly realize that the importance of an article, appearing in this journal, cannot always be judged by the prominence of its position. It so happens that in the present issue the last article in order of position is one of the most interesting. Lest those who are not mathematically inclined be frightened by the appearance of a few formulæ, and pass the article by, we take this occasion to recommend to their particular attention Professor Scripture's paper on the "Nature of Vowel Sounds."

Professor Scripture had for his aim to produce a church organ which would be of material assistance to the choir and the congregation. It is a well-known fact that many singers are very careless in pronouncing consonant sounds. Most of the consonants are so short and of such an explosive nature that it is very easy to lose them completely in singing, so that what the audience hears is mainly a succession of vowel sounds. If the hearer is familiar with the music and the words he supplies mentally what his ear does not actually hear. Thus the choir may be singing "oh-ee oh-ee oh-ee aw aw aw-ai-ee"—at least this would be the impression upon a foreigner—but the congregation, being familiar with the air and with the words, would mentally translate the sounds into "Holy, Holy, Holy, Lord God, Almighty."

Since the consonants are of secondary importance, Professor Scripture hit upon the idea of fitting the pipe organ with a vowel-sounding register. In other words, he would provide resonators which would respond to the different vowel sounds so that the organ, instead of producing pure musical notes, would actually sing these vowels, thereby assisting the choir and the congregation. This research led to the investigation of the nature of the vowel sound, and efforts were made to determine why one voice is more musical than another.

Vowel sounds according to Helmholtz are produced by smooth vibrations with harmonic overtones, but recent investigations confirm an earlier theory first published by Willis in 1830, to the effect that the fundamentals in vowel tones are constructed of series of puffs and inharmonics. Professor Scripture produced his tones with a siren, which, as is well known, cuts a jet of air into a succession of puffs. In connection with this, he used soft resonators in imitation of the mouth and was able to obtain resonators which would respond to various vowel sounds at any pitch. In the human voice these puffs are produced by the larynx and the musical quality of the voice depends solely on the presence or absence of various qualities in these puffs. To quote Professor Scripture, "The quality of the voice that distinguishes a Caruso from a costermonger lies exclusively in the laryngeal puff." This is rather upsetting to the theory heretofore held that the resonance of the vocal cavities give the musical quality to the tone. Professor Scripture also brings out the interesting fact that every vowel sound has a melody of its own which varies with the emotion of the singer. In examining records of Caruso's voice he finds that he never keeps on a constant pitch during a vowel, but is continually making slight changes which express emotion, such as sadness, admiration, doubt, etc.

WHAT IS LUBRICATION?

SCIENCE has been likened to a complex puzzle picture, which learned men are painstakingly putting together out of a vast multiplicity of blocks known as "theories." Many blocks are tried and rejected before one is found that fits perfectly into its surroundings. Sometimes in despair of getting a perfect fit, a block which is a partial fit is used tentatively in the hope that other blocks may be found to fill up the chinks around it, or that later discoveries may call for changes in the surrounding blocks, which will make them conform to the outline of the apparent misfit. The more perfect the fit, the surer we are that our theory is correct, but we may never be *perfectly* sure. The picture is constantly growing and now and then a change is made that upsets a part which had been considered finished for all time.

Here is a case in point. We have always been taught to think of a lubricant as a filler of rough surfaces. Oil fills up minute inequalities and interposes a film between two surfaces, so that for the friction between the surface there is substituted the internal friction or viscosity of the oil. Recent research, however, has thrown a doubt upon the infallibility of this theory. While a well lubricated journal or surface, in which there is an actual film of oil separating the two relatively moving surfaces, does behave according to the long established theory of lubrication, when we deal with partially lubricated surfaces, we encounter phenomena which are difficult to explain. The coefficient of friction between different metallic surfaces varies not only with different lubricants, but also with the same lubricant and different metals. This has led to careful study of just what constitutes "oiliness." The problem is being investigated in England by the Lubricants and Lubrication Inquiry Committee of the Department of Scientific and Industrial Research. A preliminary report of the work of the committee is found on another page.

As a result of this research the hint is thrown out that lubrication may be a *chemical* rather than a physical phenomenon. There is evidence to support the theory that there is an actual chemical compounding of the lubricating oils and the metals which they lubricate. The evidence is not complete, but enough has been brought forward to shake our confidence in the established theory of lubrication and to suggest that we may have to rearrange this portion of our puzzle picture.

The Einstein Theories

A Physical and Astronomical Review of Their Contents and the Evidence Pro and Con

By William H. Pickering, Ph.D.

Dr. William H. Pickering, of the Harvard College Observatory in Jamaica, one of America's best known astronomers, contributed two essays to the Einstein contest. Both of these impressed the Judges as being scientific critiques of the relativity hypotheses rather than popular explanations within the intent of the contest. It goes without saying, however, that both of them are interesting and authoritative; and we believe that both are in a style that will be entirely intelligible to our readers. In one of them Dr. Pickering writes as a physicist, in the other as an astronomer. In both he conveys the impression that while he recognizes the importance of the Einstein theories, and stands ready to give them every fair hearing and a willing acceptance if they turn out to demand this, he regards them as still unproven in full.

In submitting these essays for separate consideration Dr. Pickering necessarily had to duplicate between them a considerable amount of introductory statement and general material descriptive of the Einstein theories. In order that this duplication might be gracefully eliminated, we have worked the two essays together into one. Save for omitted matter, and for one or two brief connecting links which it was necessary to substitute for such matter, the text stands exactly as written by Dr. Pickering.
—EDITOR.

THE Theory of Relativity will be treated first from the physical side, leaving the three astronomical tests to which it has been put to be discussed later. There is one astronomical fact however that must be mentioned in this connection, and this is the discovery of the aberration of light by Bradley in 1726. It is found that every star in the heavens apparently describes a small annual ellipse, whose major axis is 41″ in length. This Bradley showed to be due to a combination of the velocity of the earth in its orbit, and the velocity of light; and it is so explained in all the elementary text-books on astronomy. It implies a stationary ether through which the earth is moving. The importance of this statement will appear presently.

The subject is usually illustrated by supposing a man to go out in a rainstorm carrying a vertical tube. If the rain is falling vertically, and the man stands still, the sides of the tube will not be wet, save by an occasional drop, but if the tube is moved, it must then be inclined forward in order to keep it dry. The angle of inclination, which corresponds to aberration, will depend on the relative velocity of the tube, corresponding to the earth, and the rain drops which correspond to the waves of light.

If three lines are dropped upon a point in space, each line being perpendicular to the plane containing the other two, we have what is known as a system of coordinates. Einstein's original theory of relativity, which he now designates as the "special theory," depends on two principles. The first is that "Every law of nature which holds good with respect to a coordinate system K must also hold good for any other system K′, provided that K and K′ are in uniform movement of translation." The second principle is that "Light in a vacuum has a definite and constant velocity, independent of the velocity of its source."

These two sentences may be considered as authoritative, being quoted in Einstein's own words.[1] The first of these principles need not greatly surprise us. The second is not well expressed, because it is ambiguous. He does not say how the first "velocity" is measured, whether relatively to the ether or relatively to the observer. In fact this is the very gist of the whole matter, as we shall presently see. In the case of sound the velocity is constant with regard to the medium, the air, in the case of light it is supposed to be constant with regard to the observer. It reaches him with a constant velocity, no matter how he moves.

In order to understand this statement clearly let us consider the appended tabular diagram. On a calm day imagine a source of sound at S in line *a*. This may be either a gun or a bell. Imagine an observer 1,100 feet distant, located at O. The velocity of sound in air is 1,100 feet per second. This velocity we will take as unity, as indicated in the third column, and the velocity with which the sound reaches the observer is also 1, as shown in the fourth. It will reach him in a unit interval of 1 second, as shown in the fifth. If the bell is struck, it will give its normal pitch or frequency, which we will also call unity, in the sixth column.

Now imagine case *b* where the observer is on a train advancing toward S. When he is 1,100 feet distant, the gun is fired, but as he is advancing toward it, he hears it at O in rather less than a second, as shown in the fifth column. The velocity of the sound with regard to him is rather more than unity, as shown in the fourth column. If the bell is sounded, the pitch, that is the frequency, is raised, because he receives more sound waves per second than before.

In case *c* the observer is stationary, but the source of sound is receding. At a distance of 1,100 feet the gun is fired, and the observer hears it after an interval of just one second, as in case *a*. The velocity with regard to the observer and through the medium are also unity. If the bell is struck the pitch is lowered, since he receives fewer sound waves per second, the reverse of case *b*.

Table I

Case	Source	Velocity in Medium	Velocity to Observer	Interval	Frequency	Observer
			Air			
a	S	1	1	1	1	O
b	S	1	1+	1−	1+	O
c	S	1	1	1	1−	O
d	S	1	1+	1−	1	O
			Ether			
A	S	1	1	1	1	O
B	S	1−	1	1	1+	O
C	S	1	1	1	1−	O
D	S	1−	1	1	1	O

In case *d* imagine the source and the observer 1,100 feet apart, and advancing on the same train. When the gun is fired, the velocity of the sound waves will be greater with regard to the observer, and he will hear the sound in less than a second, as in case *b*. When the bell is struck it will have the normal pitch, the same as in case *a*.

We find therefore that for sound the velocity with regard to the medium is always unity, while the velocity with regard to the observer, and the interval elapsed, depend only on the motion of the observer himself, and are independent of the motion of the source. The frequency of the vibrations, on the other hand, depends only on the relative motion of the

[1] *Journ. Brit. Astron. Asso.*, 1919, 30, 76.

observer and the source, but is independent of their common motion in any direction. Further, it makes no difference whether the source and the observer are moving on a train, or whether they are stationary, and a uniform wind is blowing past them.

In the case of light waves we shall find a very different state of affairs, although the rules for frequency are the same as they are for sound. In case *A* we have the normal conditions, where both the source and observers are stationary. In case *B* we have a representation of the Michelson-Morley experiment as supplemented by that of Majorana,[2] where the source is stationary and the observer advances. Unlike the case of sound, the interval elapsed, as shown by the experiment, is now the same as in case *A*, and since the distance to the observer is less, the velocity of light with respect to the ether must also be less than unity. Since the observer is advancing against the light, this will permit the velocity of light with regard to the observer to remain unity, in conformity with the second principle of relativity. Compare with case *b* for sound. As Jeans expresses it, "The velocity of light in all directions is the same, whatever the motion of the observer."[3] That is to say it appears to be the same to him, however he moves.

Case *C* represents Einstein's statement, as confirmed by Majorana's experiment. It does not differ from case *c* for sound. Case *D* is more complex, but accepting the statement above that the velocity is constant with regard to the observer, we see that the velocity through the medium must be less, and that the interval elapsed will be constant, as in case *B*. Could we use the brighter stars and planets as sources of light, several of these cases could be further tested.

This brings us at once to statements that contradict our common sense. For instance, Jeans says "no matter what the velocity of the observer is, the light surface, as observed by that observer, is invariably a sphere having that observer as center."[3] That is to say the light surface, or wave front, is a contracting, not an expanding, sphere. This, if confirmed, would go a long way toward making our universe a subjective rather than an objective phenomenon. Again imagine a flash of light, such as an explosion, to occur when an observer is in a given position. It makes no difference how the observer may move while the light is approaching him, whether several miles forward or backward, the light will reach him in exactly the same time, as is shown by Michelson's experiment. Or if two observers are at the same spot when the explosion occurs, and one moves forward, and the other backward, they will both see the explosion at exactly the same instant.

This sounds ridiculous, but not only is it what Jeans says, but it is the logical interpretation of Einstein's second principle, if Einstein means by velocity, velocity with regard to the observer. If he means velocity with regard to the medium, then the case is exactly the same as that of sound in air, and Michelson's experiment as well as the Maxwell-Lorentz theory of light is contradicted. This theory is now universally accepted, and Michelson's experiment has been carefully repeated by other observers, and fully confirmed. This is the very heart of the relativity question.

If we state the matter objectively it comes to this. The velocity of light with regard to the ether is a variable quantity, depending merely on where the observer chooses to go. As Eddington well says, "these relations to the ether have no effect on the phenomena and can be disregarded—a step which appears to divest the ether of the last remnants of substantiality."[4]

The only way of avoiding this apparent absurdity seems to be to consider that the ether moves with the earth. Michelson's result would then be fully explained. Of course this can only be true for a few miles above the earth's surface. Beyond that the ether must either be stationary or move with the sun. The velocity of light with regard to the ether would then be a constant, just as the velocity of sound is constant with regard to the air. This would contradict Einstein's second principle as it is generally understood. The trouble with this suggestion is that it fails to account for aberration, which, as already explained, appears to require that the earth should be moving through the ether. To meet this emergency would involve some modification of the undulatory theory of light, which apparently would not be impossible, but has not yet been made.

In 1915 Einstein brought out an extension of his first principle. This he calls the "general theory of relativity." It states that in our choice of coordinate systems we "should not be limited in any way so far as their state of motion is concerned."[1] This leads to the three astronomimcal consequences mentioned later in this paper, two of which have been more or less confirmed, and the third practically contradicted as fas as quantitative measures are concerned.[5]

As is well known the kinetic energy of a moving body may be expressed as $e = \frac{1}{2}mv^2$, but if the body is charged electrically, the fraction becomes $\frac{1}{2}\ (m + m^1)v^2$, where m' is a quantity dependent on the square of the electrical charge. That is to say, we have the normal mass of the body, and also what we may call its electrical mass. If when in this condition a portion of the mass is electrical, the question at once occurs to us, why may not the whole mass be electrical, in other words, a form of energy? Although this has not been satisfactorily proved hitherto, yet such is the general belief among physicists. As Einstein puts it "inert mass is nothing else than latent energy."[1] The same idea is sometimes expressed as "the mass of ordinary matter is due to the electromagnetic energy of its ultimate particles, and electromagnetic energy wherever found must possess mass, *i.e., inertia.*"[3] If that is so, since a ray of light on the undulatory theory is a form of electromagnetic energy, it too must possess mass. Since all mass with which we are familiar is subject to the attraction of gravitation, it seemed likely that a ray of light would be bent out of its course in passing near the sun, and this as we have seen was proved to be true at the recent solar eclipse.

That portion of the mass of a body due to its electrical charge can be readily shown experimentally to vary with the velocity of the body. Einstein has shown the same to be true of the normal mass, as is illustrated in the advance of the perihelion of the orbit of Mercury. He has also pointed out that gravitation, inertia, and centrifugal force are all closely related, and obey similar laws. Thus if we rise from the earth with accelerated velocity, we apparently increase our weight. Again if the velocity of rotation of the earth on its axis should be increased, our weight would be diminished. These facts are suggestive when we come to consider the ultimate cause of gravitation.

Another fact which must be rather startling to the older school of scientists is that momentum is no longer simply mv, mass times velocity, but that the velocity of light c, comes into the question, and the formula for momentum now assumes the form of

$$\frac{mv}{\sqrt{1 - \frac{v^2}{c_2}}}$$

For ordinary velocities this correction is extremely small, but it has been shown to be necessary, both theoretically and experimentally, when dealing with the higher velocities with which we are now familiar.

The theory of relativity is so widespread in its application that several other theories have become more or less intimately combined with it, for which Einstein is in no way responsible. One of these is known as the Fitzgerald-Lorentz theory, that all bodies are subject to a contraction in the di-

[2] *Comptes Rendus*, 165, 424, and 167, 71.
[3] *Monthly Notices R. A. S.*, 1919, 80, 104.
[4] *Monthly Notices R. A. S.*, 1917, 77, 379.
[5] *Astro-Physical Journal*, 1917, 46, 249. *Journ. Brit. Astro. Asso.*, 1920, 30, 276.
[6] *Monthly Notices, R. A. S.*, 1917, 77, 377.

rection of their motions through space. This was first suggested in order to explain the Michelson-Morley experiment, but has proved inadequate to do so, particularly when the observer is receding from the source. This contraction is expressed by the same factor used in the denominator of the revised expression for momentum, given above. Again the quantity c is so enormous, that even for large bodies at planetary velocities the contraction amounts to very little. Thus the earth moving at a speed of eighteen miles per second in its orbit, is flattened only 1/200,000,000, or 2.5 inches. On the other hand for high velocities of many thousand miles per second, such as we have become familiar with in the case of the radio-active substances, the flattening is a very considerable fraction of the diameter of the moving body, one-half or more, and in the case of the corpuscles of light, if that theory were adopted, this flattening becomes equal to the diameter, and their thickness is reduced to zero.

When we view Einstein's theories from the astronomical standpoint, the earliest fact bearing on relativity that we need consider was the discovery of aberration, by Bradley, in 1726, as seen above. In 1872 Airy observed the star γ Draconis through a telescope filled with water. Since the velocity of light is less in water than in air, we should naturally expect to find the aberration appreciably increased. It was found, on the other hand, however, to be unaffected.

In 1887 the results of the famous Michelson-Morley experiment were published.[7] In this experiment the velocity of light was measured in various directions with regard to the motion of the earth in its orbit. If the ether were stationary, and the earth moving through it, different velocities should be obtained in different directions. Such was not the case however, and the experiment indicated that the ether moved with the earth. It thus flatly contradicted the conclusions founded on aberration.

Einstein's Special Theory of Relativity, of 1905, as we have seen, resolves this contradiction. But as we shall presently see, it is the General Theory, of 1915, that leads to astronomical applications of broad scope. It indicates, for instance, that there is no essential difference between gravitation and inertia. This idea may be crudely illustrated by our feelings of increased weight when an elevator starts rapidly upward. A man while falling freely in space ceases to feel the pull of gravitation.

But we must not as yet conceive of the theory of relativity as a universally accepted and unquestioned truth of science. Eddington is its leading English exponent, and he is supported by such men as Jeans, Larmor, and Jeffreys. On the other hand, the theory has been severely criticised by Lodge, Fowler, Silberstein, and Sampson. Few American scientists have expressed any opinions in print on the subject, and the recent eclipse observations, to which we shall refer later, are to be repeated with more suitable instruments for verification in 1922, in the hope of obtaining more accurate and accordant results.[8]

An appurtenance of the Einstein theories which bears much the same relation to it as does the Lorentz-Fitzgerald contrac tion, mentioned above, is the idea, first clearly stated by Minkowski, that time is a kind of space—a fourth dimension. This the reader will doubtless find to be the most difficult portion of the theory to picture in his own mind. It is entirely unsupported by experiment or observation, necessarily so, and is based wholly on mathematical and philosophical conceptions. Our distinction between space and time seems to be that the direction in which we progress without effort is time; the other directions, in which we have to make an exertion to move ourselves, or in which we are carried, are space. How many dimensions empty space may have, we really have no means of knowing, because we can neither see nor feel it. Matter we know has three, length, breadth, and thickness, also that it lies remote from us in three corresponding directions. These facts may have given us the erroneous impression that space too had only three dimensions. Now it is claimed that time is a fourth, and that there are also others.

In order to illustrate this, Eddington asks us to imagine a movie film taken of a man or of any other moving object. Let the separate pictures be cut apart and piled on one another. This would form a sort of pictorial history of the individual for a brief interval in his life, in the form of a cube. If we attempt to pick it up, it falls apart, thus clearly showing the difference between time and space. But suppose it now all glued together in one solid cube, so that it is no easier to cut a section in one direction than in another. That is Minkowski's idea of space and time, and further, that the direction in which we should cut it depends merely on the velocity with which we are moving through space. I should cut it parallel to the films, but a man on a rapidly moving star, in order to separate it into space and time, would cut it in an inclined direction. That is a thing which may be true, but it is one which we believe no mortal man can clearly picture to himself.

On the other hand Turner has recently made a very interestin point,[9] namely, that the fourth dimension as actually treated by the mathematicians is not time itself, but time multiplied by a constant—the velocity of light.[10] Without affecting the astronomical proofs of relativity at all, this simplifies our conceptions enormously. In ordinary everyday life time and space cannot be identical, any more than a yard can be identical with a quart. On what is known to physicists as the centimeter gram-second system, distance is represented by l, mass by m, and time by t. Velocity is then distance divided by time, $\frac{l}{t}$, or as we say in English units, so many feet per second, and the fourth dimension may be expressed as time multiplied by velocity, $t \times \frac{l}{t} = l$. That is to say, it is simply distance, just like the other three dimensions. To say that time is the fourth dimension from this point of view, appears to us just as ridiculous as it would be to attempt to measure the velocity of a train in quarts. It is quite correct, however, although unusual, to speak of a given train as moving at a speed of 10 quarts per square inch per second, $\frac{l^3}{l^2 t} = \frac{l}{t}$. This would be equivalent to a velocity of 33 miles per hour.

If I wish to give a complete dimensional description of myself in my four dimensions, I must give my length, my breadth, and my thickness, ever since I came into being, and also the course I have traversed through space since that time. This latter distance will be expressed in terms of a unit whose length is 186,000 miles, the distance traversed by light in one second. The distance which I travel through space annually is enormous, and very complex as to direction. It involves not merely my own motions as I cross the room, or take a train or steamer, but also those due to the rotation of the earth on its axis, its revolution round the sun, and the motion of the latter through the heavens. In general I travel, or in other words increase my length in the fourth dimension, by over 4,000 units a year. The fourth dimension accordingly, if this view is accepted, is simply a distance like the other three, and perfectly easy to understand.

We now come to the three actual tests by which the theory has been tried. The planets as is well known revolve about the sun in ellipses, with the sun in one of the foci. That is to say, the sun is not in the center, but a little to one side of it. The end of the ellipse where the planet comes nearest to the sun is called the perihelion, and here the planet is moving most rapidly. The other end is called the aphelion, and here the motion is slowest. According to Newton's theory of gravitation, if a spherical sun possesses a single planet or

[7] *Amer. Journ. Sci.*, 34, 333.

[8] *Monthly Notices, R. A. S.*, 1920, 80, 628.

[9] *The Observatory*, 1920, April. From an Oxford Note Book.

[10] *Monthly Notices, R. A. S.*, 1917, 78, 3 *De Sitter*, 1919, 80, 121, Jeans, 80, 145 Jeffreys.

companion, its orbit will be permanently fixed in space unless perturbed by some other body. If a second planet exists, it will cause the perihelion of the first slowly to advance. According to Einstein the mass of a planet depends in part on its velocity. It will therefore be less at aphelion where it is moving slowly than at perihelion where it is moving rapidly, consequently in addition to the Newtonian attraction we have another one which increases as we approach the sun. The effect of this will be to cause the perihelion of the orbit to advance, whether there is a second planet or not.

Among the larger planets Mercury has the most eccentric orbit, and it also moves most rapidly, so that it is particularly well adapted to test the relativity theory. The observed advance of its perihelion is 574″ per century, instead of the theoretical figure 532″, due to the other planets—a difference of 42″.[11] This has long been a puzzling discrepancy between observation and the law of gravitation. Prior to Einstein, attempts were made to eliminate it by assuming a certain oblateness of the solar disk. If the equatorial diameter exceeded the polar by only 0″.5 the whole advance would be accounted for, but not only has this ellipticity failed of detection, but if it existed, it should produce a very noticeable and inadmissible change in the inclination of Mercury's orbit, amounting to about 3″ per century, as has been demonstrated by both Herzer and Newcomb.[12]

Einstein from computations alone, without introducing any new constants or hypotheses whatever, showed, if the theory of relativity be accepted, that the sun should produce an acceleration of 43″ per century, thus entirely accounting for the observed discrepancy, far within the limits of accuracy of the observations. The only other planet whose orbit has a large eccentricity, and that is suitable for investigation, is the planet Mars. Here the discrepancy between observation and theory is very slight, only 4″, and a portion of that may be due to the attraction of the asteroids. This deviation is so slight that it may well be due entirely to accidental errors of observation, but however that may be, Einstein's theory reduces it to 2″.7.

This all seems very satisfactory and complete, but the trouble with it is that the coincidence for Mercury is rather too good. It is based on the assumption that the sun is a perfect sphere, and that the density of its surface is uniform from the equator to the poles. This would doubtless be true if the sun did not revolve on its axis. In point of fact it does revolve, in a period in general of about 26 days. Consequently an object on its equator must experience a certain amount of centrifugal force. Therefore if its surface were of uniform density the sun would be an oblate spheroid.

It can be readily shown that the theoretical excess of the equatorial over the polar diameter, due to the centrifugal force, should amount to only 0″.04, an amount which could hardly be detected by observation, and might readily be concealed by a slight excess of equatorial over polar density. Any reasonable excess of density at the center would diminish this result but slightly. The molecular weight of the central material is probably about 2.[13] This computed equatorial excess is one-twelfth of the amount necessary to cause the observed advance, and should therefore cause an advance of the perihelion of about 3″.5 per century, reducing the difference between the observed advance, and that caused by gravitation to 38″.5. According to Einstein the advance due to relativity should be, as we have seen, 43″, a discrepancy of 4″.5 per century, or 10 per cent. Jeffreys has remarked that any discrepancy such as 10″ "would be fatal to a theory such as Einstein's, which contains no arbitrary constituent capable of adjustment to suit empirical facts.[14] It must be pointed out here however, that so far as known, this small correction to the motion of Mercury's perihelion has not previously been suggested, so that there has been no opportunity hitherto for its criticism by others.

It was due largely to the success with Mercury that it was decided to put the relativity theory to another test. According to the Newtonian theory, as stated by Newon himself, corpuscles as well as planets have mass, and must therefore be attracted by the sun. According to Einstein, owing to their high velocity, this attraction must be twice as great as it would be according to the theory of gravitation. If the ray of light proceeding from a star were to pass nearly tangent to the sun's limb it should be deflected 0″.87 according to Newton. According to the theory of relativity it should be deflected 1″.75. Stars of course cannot usually be observed near the sun. It is therefore necessary to take advantage of a total solar eclipse, when the sun is completely hidden by the moon.

Two expeditions, one to Africa, and one to South America, observed successfully the total eclipse of May 29, 1919. The former was located on the island of Principe in the Gulf of Guinea. The latter was located at Sobral, Brazil. Their equipment and results are shown in the following table, where the successive columns give the location, the aperture in inches of the telescopes employed, their focus in feet, the number of plates secured, the number of stars measured, their mean deduced deflection from their true positions by the attraction of the sun, and the deviations from the theoretical results.[15] In the first and last line of the table as here presented this deviation is taken from Einstein's computed value of 1″.75. In the second line the difference shown is from the value required by the Newtonian theory 0″.87. The results obtained with this telescope were rejected however, although they were much the most numerous, because it was found that for some reason, supposed to be the heating of the mirror by the sun before the eclipse, the star images were slightly out of focus, and were therefore considered unreliable. The results with the two other telescopes were not very accordant, but the 4-inch had the longer focus, secured the greater number of plates, and showed the greater number of stars. The results obtained with it therefore appear to have been the more reliable. They differ from Einstein's prediction by 13 per cent.

TABLE II

Location	Aperture	Focus	Plates	Stars	Defl.	Dev.
Principe	13	11	2	5	1″.60	−0″.15
Sobral	13	11	19	12	0 .93	(+0 .06)
"	4	19	8	7	1 .98	+0 .23

We now come to the final test which has been applied to Einstein's theory. Einstein showed that in the intense gravitational field of the sun, the theory of relativity required that all of the spectrum lines should be shifted slightly toward the red end. The shift however is exceedingly small, and can only be detected and measured with the most powerful modern instruments. Moreover only certain lines can be used, because owing to varying pressure in the solar atmosphere, which affects many lines, as well as to rapid motion in the line of sight, which may affect all of them, still larger displacements are liable to occur.

According to the theory of relativity the displacement of the lines should be + 0.0080 A. St. John at Mt. Wilson found a displacement for the cyanogen lines of only + 0.0018 A.[16] Evershed at Kodaikanal found + 0.0060 at the north pole of the sun, and + 0.0080 at the south pole. These latter values however were only for the stronger lines. The weaker lines give much smaller shifts, as do those of calcium and magnesium.[17] According to Einstein all lines should give nearly the same shift, an amount proportional to the wave length. It therefore appears that we must conclude by saying that Einstein's theory of relativity has been partially, but not completely, verified.

[11] "Gravitation and the Principle of Relativity," Eddington. Royal Institution of Great Britain, 1918.

[12] *Journ. Brit. Astron. Assoc.*, 1920, 30, 125.

[13] "The Interior of a Star," Eddington. *Scientia*, 1918, 23, 15.

[14] *Monthly Notices, R. A. S.*, 1919, 80, 138.

[15] *Monthly Notices, R. A. S.*, 1920, 80, 415. *Journ. Brit. Astron. Asso.*, 1919, 30, 46.

[16] *Astro-Physical Journ*, 1917, 46, 249.

[17] *Journ. Brit. Astron. Assoc.*, 1920, 30, 276.

Cloud Photography*

Construction of Apparatus and Methods of Procedure

By Arthur J. Weed

THE first requisite in cloud photography is a good camera for that special purpose. Not necessarily an expensive apparatus, but one that is rigid and has the necessary means of attachment to a firm support.

A suitable ray filter, or black mirror, is necessary to cut out the actinic light of the blue sky and render, in the finished print, white clouds on a dark background just as we see them on a darker background of blue.

Excellent pictures may be made of certain types of clouds with a light bellows camera, when it is sheltered from the wind, but if one wishes to do really good work this will be found too light and shaky for the purpose, as some of our most interesting clouds occur only when a strong wind is blowing.

In order to get an unobstructed view, means should be provided for mounting the camera on the highest possible elevation like the top of a hill or the roof of a building.

Fig. 1 shows a camera built by the writer at Mount Weather Observatory. Two permanent mountings were required for a full sweep of the horizon, each of which consisted of a piece of yellow pine timber 3 by 4 inches, the upper end turned to a diameter of about 3 inches. These turned portions of the posts were shellacked and when not in use were protected by metal covers made from pieces of tubing with a head soldered into one end. The method of attaching the post to the metal railing is shown in the photograph.

FIG. 1. CLOUD CAMERA (ON LEFT) USED AT MOUNT WEATHER AND PICKERING POLARIMETER (ON RIGHT)

The holder for the camera consisted of a tube to fit over the turned wood post, a frame to hold the bed of the camera, and two braces by which the vertical adjustments were made. The tube was a piece of conduit pipe used to protect underground electric wires. To the top of the tube was secured a crosspiece of wood, and to this was hinged one end of the frame carrying the camera bed. To the other end of the frame two round metal braces were attached by hinges. The tube was sawed open from the bottom for about one-half its length and a U-shaped strap of brass was placed around it. Through the free ends of this brass strap a bolt was inserted on which were two pairs of thick washers, each pair grooved to hold one of the metal braces of the frame. The bolt was provided with a large milled head nut. When this nut was tightened the camera was firmly secured both vertically and horizontally. The frame was constructed so that the bed of the camera slid in between the two side rails where it was secured in position by four large-headed brass bolts provided with milled head nuts. The heads of these bolts gripped the edge of the camera bed. This frame could be swung around on the post and had a vertical movement of 90°.

The camera consisted of a bed or frame, made from a piece of maple flooring, on which were mounted two wooden boxes painted a dead black on the inside and constructed of the proper size to telescope together readily. The outer box was screwed to the camera bed and the front end of the inner box was secured to a maple frame having an L-shaped extension which was fitted to slide on the maple bed. This frame carried the lens board. The arbitrary sizes to be followed in constructing such a camera are that the combined length of the two boxes plus the lap where they slide together shall equal the focal length of the lens it is desired to use. Also the outer box must conform to the size of the plate holder used so that a light trap can be arranged. In this particular camera a groove was made at the top and bottom of the rear end of the outer box a little wider than the thickness of the plate holder, and a flat spring was fastened in the outer edge of each groove which forced the plate holder against the end of the camera box. The ground-glass focusing screen was mounted in a frame corresponding in size to the plate holder and had to be removed before inserting the holder. When only one lens is to be used with such a camera the two boxes can be adjusted to get the proper focus of a distant object on the ground glass and then firmly secured to the bed at that point. The only use for the focusing screen thereafter is to see just how much of the view will appear in the picture.

For quick work a special view finder was made and attached to the camera. This was in two parts, as shown in Fig. 2. A rectangular frame proportional to the size of the plate to be used was mounted on the top of the camera box and had both a vertical and a horizontal wire stretched across it, meeting at the center. This frame was mounted so that it could be folded down upon the top of the camera and was retained in either position by a bent flat spring, the free ends of which pressed against the bottom or side of the frame. Behind the frame, extending lengthwise of the camera, was a round rod mounted on supports at each end and having the underside flattened. Sliding on this rod was a vertical post with a small ring at the top to sight through. The center of this ring was level with the cross wires in the frame. A

*From *The Monthly Weather Review*, August, 1920.

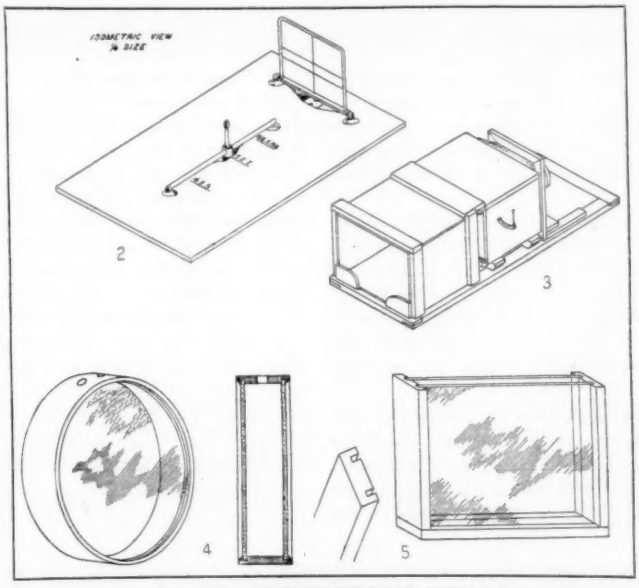
spring attached to the lower end of the post and pressing up against the flattened portion of the rod held the post vertical. When not in use this post could be turned down on either side of the rod and out of the way.

The frame was in exact proportion to a 6½ by 8½ plate, that being the size of plate holder used with this camera. The vertical post was adjusted to such a position on the rod that when one sighted through the ring all that was visible inside the frame would also be shown on the ground glass of the camera. This position was then marked on the top of the camera. The dimensions of a 5 by 7 and a 4 by 5 plate were marked in pencil on the ground glass of the camera. The vertical post of the finder was then adjusted to show both these views approximately, and the corresponding positions of the post were marked on the camera. This allowed the use of small plates in the 6½ by 8½ holders by using "kits," and the camera could be quickly sighted on a changing cloud, the finder showing just what would be included in the picture.

Fig. 1 shows the camera as at first constructed, but considerable difficulty was experienced in using a focusing cloth on windy days. Another box was therefore constructed of light material corresponding in width and height to the outer box of the camera. This was of sufficient length to occupy the rear projection of the camera bed and proved to be a valuable acquisition, as, in addition to forming a focusing hood, it also supplied a location for the plate holders. A line drawing of the completed camera is shown in Fig. 3.

The back of this box was left open, except for two small pieces of thin wood set across the two lower corners. These retained the plate holders when the front of the camera was elevated to sight on a high cloud.

On this side of the camera box was placed an inclinometer. This consisted of a short piece of fine brass wire having a loop bent in the upper end and a flat-pointed weight soldered to the lower end. A small brass screw was inserted through the loop and then screwed into the side of the camera box. The wire could swing free on the screw and the weight hang vertical. The camera was then leveled and a brass sector, graduated from 0° to 90°, was placed in position, so that as the camera was tilted upward the angle from the horizon to which it was elevated would be indicated by the pointed end of the hanging weight. This should be boxed in and have a cover of glass or celluloid, otherwise it must be sheltered from the wind while the angle is being read.



FIGS. 2-5. CONSTRUCTIONAL DETAILS

2, View finder; 3, cloud camera complete; 4, details of ray filter cell; 5, tank for dyeing ray filters.

In this branch of photography, as in all others, a good lens is to be desired. The lens used for most of the cloud pictures shown with this article was a Goerz 10½-inch Double Anastigmat, F.7.7, the property of Prof. A. J. Henry, who was then the Official in Charge at Mount Weather.

Occasionally a creditable cloud picture may be made with the lens alone. This applies particularly to the gray clouds. But for white clouds in a blue sky either a ray filter or black mirror must be used.

When the camera is pointed at the sky we see on the ground glass the white clouds on a darker background of blue sky; but when these same rays of light are allowed to fall on the ordinary sensitized plate the blue and violet rays from the sky are so much more actinic than the light rays reflected from the clouds that when the cloud has been properly exposed the sky is overexposed and, in consequence, the contrast between the blue and white is entirely lost, and the finished print shows only a bare patch of white for the sky. If, however, a ray filter of the proper color is placed on the front of the lens, these intensely actinic rays of blue and violet are filtered out and the resulting print shows a white cloud on a dark background. In practice the filter should be only sufficiently deep in color to give the required contrast without unnecessarily increasing the length of the exposure.

The first filters used on this camera were cells filled with colored liquid. These were made by using a fairly thick piece of brass tubing. A ring about ½ inch long was cut from the tube and either end bored out to form a recess for the glass plates as shown in Fig. 4. Two holes were drilled in this ring and each tapped for a screw plug. These holes were for filling and cleaning the filter. A deposit will sometimes form on the inside surface of the glass plates which it is necessary to remove with a small tuft of cotton, held in a twisted loop of fine wire. If the filter is cleaned often enough a stream of water driven into one hole and escaping from the other will be sufficient to remove all deposits from the glass. The two holes are placed as close together as possible, and in filling the cell one acts as a vent when the solution is introduced through the other. The glass sides were made from lantern slide covers, which were selected so that there should be no spots or flaws in front of the lens. To cut the glass to the required size one was placed on a sheet of paper on which was drawn a circle the size of the recess in the brass ring. A glass cutter was used to square the lantern slide cover to the same dimensions as the diameter of the circle. Leaving the plate on the circle the corners can be cut off so that the plate is an octagon and if the cutter is in good condition the eight corners can be trimmed off leaving the glass nearly round. The remainder of the fitting may be done with a sharp file wet with a solution of camphor dissolved in turpentine or the glass may be ground on a stone with water as a lubricant. In either case some care is required to prevent scratching the surface of the glass. When the glasses have been fitted and cleaned they are placed in position and cemented with thick shellac. As soon as this hardens the cell is ready for use.

Potassium bichromate dissolved in water, and afterward filtered makes an excellent solution for summer use. Distilled water should be used if possible, and the ingredients carefully measured so that in refilling the cell the same density of color will be obtained as in the original solution, and, in consequence, the same length of exposure required. The best method is to make up enough of the solution for several fillings and filter it into a bottle for future use. To prevent evaporation the cork should be dipped in melted paraffin before inserting in the bottle.

Where one wishes to obtain winter cloud pictures there is the danger that this type of filter may freeze. For this

reason as stated gelatin filter is best. Such a filter may be purchased from the larger supply houses or can be made up from a dry plate.

To construct a stained gelatin filter place an undeveloped dry plate, or lantern slide plate, in the hypo bath until the silver is all dissolved and the plate becomes clear. Wash out the hypo as with a regular fixed plate and it is ready for staining. If the plate is allowed to dry after washing it should be soaked up again just before staining. For a yellow stain a few grains of picric acid dissolved in water may be used, but as this acid is rated as an explosive it is sometimes difficult to procure. Ammonium picrate may be substituted, or a good aniline dye may be used.

FIG. 6. DISTANT LIGHTNING ON "POLYCHROME" PLATE

For dyeing gelatin filters the writer uses a deep but narrow tank so that the plate will stand vertically, or nearly so. The sides of the tank were made from two 4 x 5 dry plates from which the gelatin films had been removed. The two ends and bottom were made from strips of hard rubber with two grooves milled in them into which the glass plates were cemented as shown in Fig. 5.

The dye should be prepared and filtered to remove all particles which might settle on the soft gelatin surface and cause opaque spots. Place the plate in the tank so that it tilts over to one side and the dye can be poured upon the glass side and not directly upon the gelatin film as it would make too deep a color at one spot. The film will take the color very quickly and should be removed from the tank immediately, rinsed and set up to dry.

In some instances it is desirable to show the landscape with the clouds. This requires a ray filter in which the color shades from a clear glass to the depth necessary for a cloud well up in the sky. This tank will be found well adapted for the making of such a filter. Place sufficient dye in the tank to stand at a height of about ¾ inch. Lower the prepared plate into the dye and immediately run water into the tank until it overflows and the water runs away clear. On removing the plate it will be found that because of the gradual dilution of the dye in the tank the gelatin film will be shaded from a deep color at the bottom of the plate to clear glass at the top.

When the plate has been dried a section can be selected from which to cut the filter to suit the requirements.

The finished filter may be left in a square or rectangular shape or cut round in the same manner as previously described for the filter cell. Whatever the shape decided upon, a cover glass the same size and shape should be cut and the two cemented together with Canada balsam. This protects the gelatin film from injury.

Provision must be made for holding the filter in front of the lens—either something to slip over the lens hood or an independent mounting attached to the camera front. Whatever the means employed it is important that the back of the filter be shaded from the sun so that no reflected light can enter the lens.

On completion of a filter it is necessary to time it for the proper exposure, which can be accomplished by the sacrifice of one plate. From an exposure meter get the normal time of exposure required for the stop which it is desired to use, time of day, etc. Draw the plate holder slide a short distance and make an exposure corresponding to the above data. Draw the slide a little farther and make the same exposure. Continue this until the slide is entirely withdrawn. When this plate is developed its density will be divided into strips, or sections, corresponding to the withdrawals of the plate holder slide. The last section exposed will have had *one* normal exposure and will be underexposed, for the filter will have cut down the amount of light which entered the lens. The previous section will have had *two* normal exposures and, in consequence, will show increased density and strength. The next section will give the result of *three* normal exposures, the next one *four*, etc.

Suppose the third section of the negative is found to have the required printing qualities—the filter should be marked "3T," meaning "3 times," and whenever this particular filter is used it is only necessary to multiply the normal exposure given by the exposure meter three times to give the time of exposure necessary to produce the desired density of negative. Fig. 7 shows a print from such a test negative.

FIG. 7. PRINT FROM TEST PLATE FOR TIMING RAY FILTERS

For photographing the minute details of high cirrus clouds a black mirror is superior to a ray filter. The mirror must be mounted in such a manner that its reflecting surface stands at an angle of 33° with the axis of the lens. In this

FIG. 8. THUNDERSTORM IN SHENANDOAH VALLEY, DISTANT 5 MILES

position the rays of light which come from the blue of the sky are partially polarized and are not reflected by the mirror, while the white light from the clouds is reflected very clearly. The mirror must be a black, or very dark, glass, as an ordinary piece of clear glass blackened on the back with pigments while seeming perfect to the eye will, in nearly all cases, give a double image through the lens, one reflection from the front surface of the glass and a second reflection from the back take place. This gives the cloud a blurred outline on the negative.

In a recent publication, the name of which the writer cannot recall, it was stated that if the back surface of a piece of clear glass were roughened or ground coarse before painting it black, this double reflection would be eliminated. This is passed along as an experiment worth trying, for a good black mirror is expensive.

One objection to the use of a mirror in cloud photography is that the reflection reverses the sky in the finished print. At Mount Weather another camera was constructed on a more elaborate scale for cloud work than the one here described. This was fitted with a real black-glass mirror and means were devised for obviating the reversal of the sky, but there was no opportunity to try it out before the closing of that observatory.

The plates used for most of the pictures made at Mount Weather were "Standard Orthonon." These were found to give excellent results on white clouds but for clouds lighted up in color at sunrise and sunset "Standard Polychrome" plates were to be preferred. This latter plate was found to be well adapted for lighting pictures, being sensitive to red and yellow.

One night two "Orthonon" plates were exposed in succession on a receding storm. The third and last plate exposed was a "Polychrome," and as the storm was at that time several miles distant the lens was allowed to remain open until the lightning ceased. When developed the two "Orthonon" plates showed nothing, while on the "Polychrome" every flash was seen. This picture is reproduced in Fig. 6. In the original the

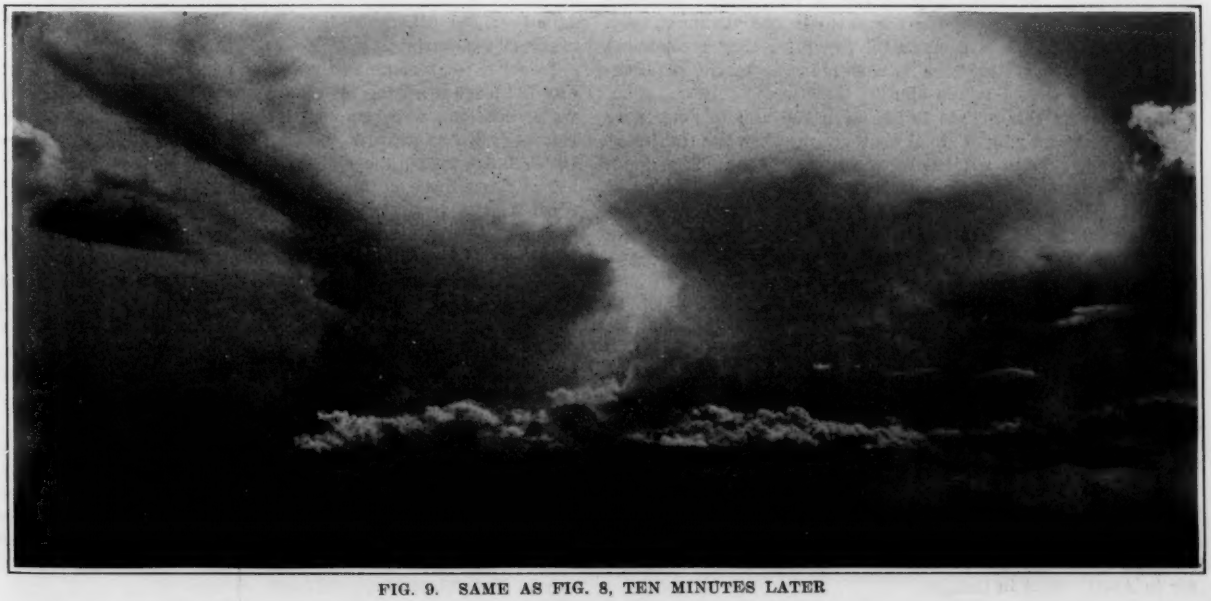


FIG. 9. SAME AS FIG. 8, TEN MINUTES LATER

contour of Bull Run Mountains can be seen, behind which the lightning was descending. This range of mountains is 20 miles distant from Mount Weather.

A rubber stamp was used for imprinting data slips similar to the following:

	Name	
No.		
Date	Time	
Direction	Angle	Filter
Lens	Stop	Exp.
Plate	Dev.	Formula
Print	Time	Dist.

As the plate holders were loaded in the dark room one of these slips of paper was marked with the number corresponding to that on the plate holder and the name of the plate therein. One slip was used for each plate. When the loaded plate holders were placed in the receptacle at the back of the camera these slips were inserted under a spring clip just above them.

After exposing a plate in the camera its slip was filled out with the name of the cloud, date, time of day, direction by compass, angle in degrees from the horizon, as shown by the inclinometer, ray filter used, lens, stop and length of exposure. These data slips were taken to the dark room with the plate holders, and after development the plates were filed away in negative envelopes as preservers, imprinted by the same rubber stamp with the above data filled in, together with the name of the developer and its formula number. The envelope was marked with the serial number of the negative, which number was also scratched in the upper corner of the film to prevent its being misplaced in printing. When prints were made, the paper used, time of printing, and distance from the light were added under their proper heading. This data adds very materially to the value of one's negatives.

As to a developer, every one has his favorite formula. Some workers claim that the long feathery lines of the cirrus are only properly brought out with hydrochinone, but if the exposure is correct there is little choice in developing agents.

Giving the right exposure means having a fast lens, and a filter only sufficiently colored to cut out the blue and adding as little as possible to the time. This is particularly necessary on a fast-moving cloud having fine detail on its edges.

Since this cloud work was done at Mount Weather the Bureau of Standards has conducted a series of experiments on plates and filters for this class of work. They state that the best plate for sensitivity in red is the "Ilford Panchromatic" and a good plate for the same is the "Cramer Spectrum Process." For a commercial ray filter they recommend "Wratten's Minus Blue," or "Kramer Isochromatic, medium-rapid, double coated minus blue."

In preparing this article it has been the aim to deal more with the how and why of cloud photography than the treatment of the subject from a meteorological standpoint. The apparatus described was made up of cheap material which could be acquired in an isolated location, yet it worked very successfully. It is not expected that the directions and suggestions here given will be followed implicitly, but that each worker will, as in this case, adapt means to ends.

In this work there is a psychological moment in which to "get your cloud" (compare Figs. 8 and 9), but, unfortunately, the game has to be played under the rules of "catch-as-catch-can." It therefore behooves the worker to be always ready. The cloud camera at Mount Weather was located just under the rafters beside the stairway to the roof, with plate holders loaded, yet many a hurried trip was made from the main floor to the roof only to find that the opportunity for a successful picture had passed.

Aside from its meteorological value the work has all the fascination of hunting big game without its attendant danger, and there is no "closed season." You will learn what to hunt for in April; what in October.

A cumulus cloud is easy to get, but how many really good photos have you seen of change cirrus, mammatocumulus, or scarf cloud? These are a few samples of the big game which it pays to go after, and to be able to exhibit a good specimen picture of such a cloud will be found as satisfactory as the showing of a pair of antlers.

DEGREE OF TEMPERATURE TO WHICH SOILS CAN BE COOLED WITHOUT FREEZING

By George Buoyoucos

THE general impression seems to be that when the temperature of soils falls slightly below the freezing point (0° C. or 32° F.) they freeze, that is, the soil moisture is converted into ice. This is hardly the case, however. In conducting investigations to study and measure the different forms of water in the soil by means of the dilatometer method and to study and measure the concentration of the soil solution directly in the soil by means of the freezing-point method, it was discovered that it is almost impossible to freeze the soils when they are cooled only slightly below the freezing point. This is true even when the concentration of the soil solution is exceedingly small and the freezing-point depression consequently negligible. Indeed, it was found that it is difficult to start solidification in the soils unless they are supercooled at about 1° C. below their true freezing point. Even at this degree of undercooling freezing begins only with vigorous agitation. If the soil is not vigorously agitated or disturbed it will remain at this temperature indefinitely without freezing. As the degree of undercooling is increased, however, the ease with which solidification is induced is also increased. Finally a temperature is reached where freezing starts automatically without agitation of the soil mass. This critical temperature is surprisingly low for all soils being about —4.2° C. (7.56° F.) for the mineral soils (sand, loam and clay), and about —5° C. (9° F.) for the peats and mucks. The maximum supercooling is still greater for water and for artificial materials, silica, carbon black, gelatin and agar amounting in all cases to about —6° C. (10.8° F.). Since water freezes at about the same degree of supercooling as the artificial materials, it would logically seem that it is the water which limits the degree of supercooling of those materials and that they themselves have no influence on the degree of supercooling of water in one way or the other.

The question now rises, why do the soils withstand a smaller degree of supercooling than the artificial materials?

No definite explanation can be offered for this phenomenon. It would appear, however, that the true explanation is to be found in the difference in the size of particles of the two classes of materials.

In order to ascertain if the degree of moisture content exerts any influence upon the resistance of soils to freezing, different water contents were employed in all the various soils. The results failed to show, however, that moisture had any appreciable influence on the resistance of soils to freezing.

The foregoing experimental results afford a new and significant insight into the temperature of soils during the cold seasons. The conclusion naturally follows that during mild winters and in mild climates in the winter the soils may not freeze even though they are cooled below their freezing point.

In the second place these findings prove quite conclusively that the method now in vogue for measuring temperature in soils in cold seasons may not give entirely the true facts. The thermometers will be recording the temperature to be several degrees below the freezing point and yet the soils may not be actually frozen.

The foregoing experimental results are very significant from still another standpoint. As it is well known, water in the liquid state has twice the specific heat that ice has. As long as the soil moisture remains in the liquid state the temperature fluctuations in the soil will be correspondingly slower and smaller.—Abstracted from the *Journal* of Agricultural Research, Nov. 15, 1920, pp. 267-269.

Prehistoric Astronomy*

New Interpretation of Some Remarkable Rock Carvings in Scandinavia

By Dr. M. Schoemfeld

THE province of Bohuslän which was originally in Norway, but now belongs to Sweden, contains the most abundant collection of the Scandinavian engravings on rocks known in the language of the country as *"Helleristninger."*

Those carvings thus far discovered were collected and reproduced by Baltzer, in his book entitled *"Glyphes des Rochersdu Bohuslän* (carvings on the rocks of Bohuslän) which was published at Götheborg in two series, which appeared respectively in 1881 and 1891.

Men of learning have long debated concerning these mysterious inscriptions seeking terms of comparison for them in the well-known legends of Nordic mythology, but the results of their discussions have been meager enough.

While examining Plate 49-50 of Series 1 in Balzer's works (Fig. 1) I was suddenly struck by the idea that it evidently contained a representation of the Great Bear and of the Milky Way in their exact relative positions. Upon making a search farther down beneath a crevice in the rock I was rewarded by finding a series of signs which recalled for the most part the classical signs of the Zodiac in their regular succession: Cancer the Crab, near Canis Minor, the little dog, Equuleus, the foal behind Pegasus and then Capricorn, the goat.

Since there seems to be no possible mistake about the matter, it only remained to interpret the figures situated between these two groups upon Baltzer's plate.

To begin with I observe two pairs of animals facing each other. Just Bing has compared these to the general type of the conventionalized pigeons found upon many Scandinavian monuments. But when we attempt to interpret the engraving in the sense of an astronomical chart we are obliged to reject this interpretation, and to identify these two pairs of animals respectively with the two hunting dogs, Canes Venatici and the two lions. While the two lower animals resemble dogs rather than lions, there is nothing to surprise us in this since the lion is an animal which is foreign to Scandinavia.

A third pair situated beneath and representing two human beings almost identical in form is readily identified with the heavenly twins Castor and Pollux. A third person who is turning his back upon the supposed figure of Pollux suggests the idea that it is meant to represent Auriga. A giant brandishing his hatchet and situated a little farther to the right may be meant for the giant Orion, while the two individuals to the left of Gemini may be Hercules and Boötes. The elongated animal to the right of the lions seems to be meant for the Lynx. A stag beneath Gemini may be meant for Draco and another lower down for the Monoceros; since these two animals are not found among the fauna of Scandinavia their transformation into stags would be only natural. Finally, the Cross placed above the Lynx probably corresponds to the *Mouche.* (*The author evidently refers to Musca—not the constellation in the southern hemisphere but a group north of Aries that formerly went by this name.*—EDITOR.)

Thus, according to this interpretation the constellations comprised between the Great Bear and the Zodiac are all represented in a succession which is partially irregular. If our interpretation appears to be debatable in certain points its general correctness is supported, nevertheless, by the fact that all of these astronomical figures are visible in the sky of the Bohuslän from September 23 to October 21 during the autumnal Equinox (Fig. 2).

Moreover, Baltzer's works contain other maps of the sky which are quite interesting. Fig. 3 represents Plates 3 and 4, No. 13 of Series II. In these we behold a long series of astronomical signs in perfectly correct order and without any accessory figures intermingled among them. In the middle is a really perfect representation of the Great Bear with the North Star directly above; to the right there follow in order the Lynx, Castor and Pollux, and Orion; to the left is Boötes the Herdsman; below are Cancer the Crab, and Leo the Lion, the latter extending along the image of a boat. If the reader

*Translated for the *Scientific American Monthly* from *La Nature* (Paris), for Feb. 5, 1921.

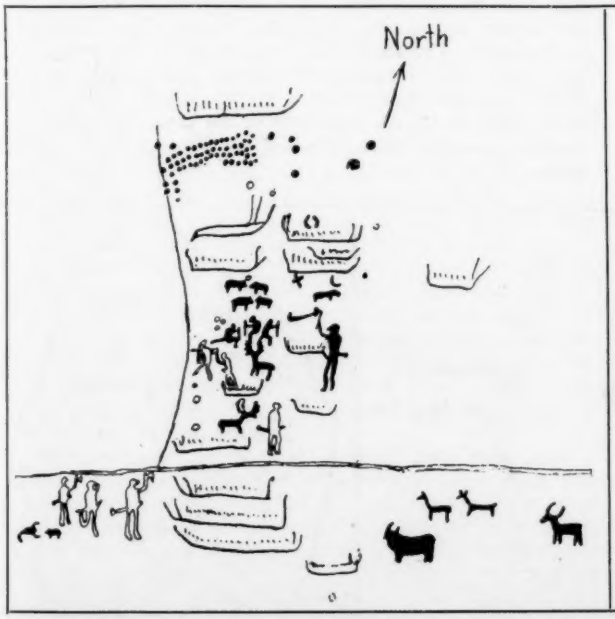


FIG. 1. ROCK CARVINGS AT BOHUSLÄN IN THE PARISH OF TANUM, AFTER BALTZER

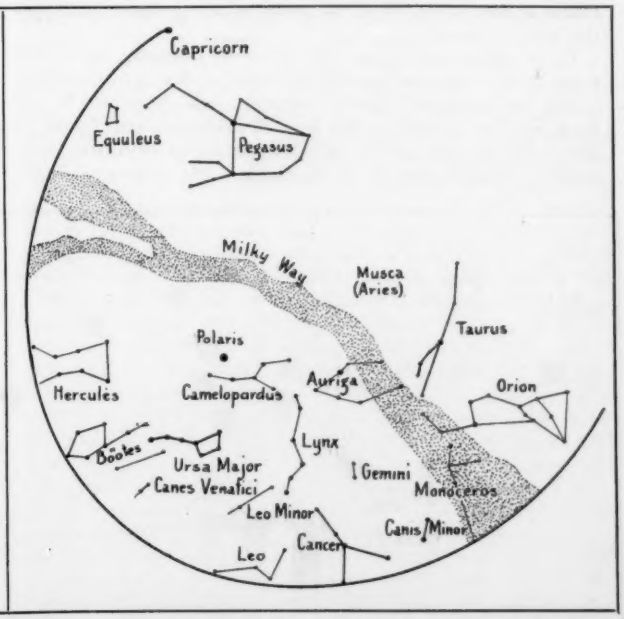
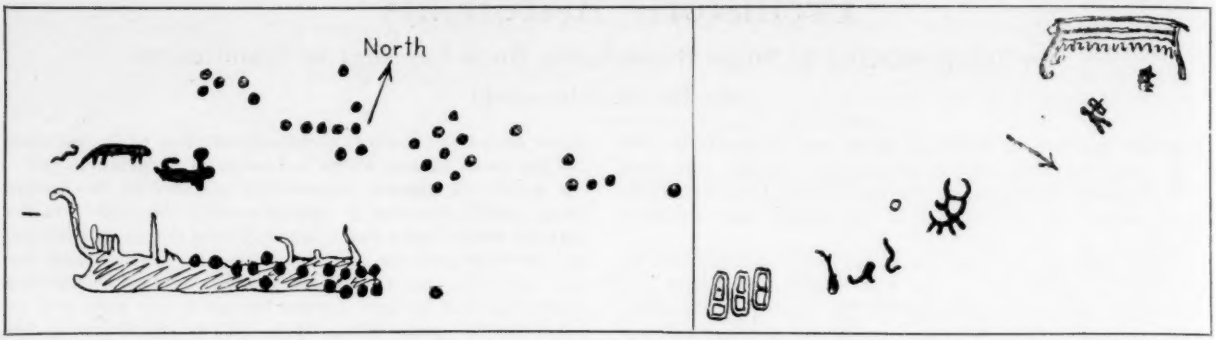


FIG. 2. CONSTELLATIONS VISIBLE IN THE SKY AT BOHUSLÄN FROM SEPTEMBER 23 TO OCTOBER 21



FIGS. 3 AND 4. ROCK CARVINGS AT BOHUSLÄN, AFTER BALTZER SERIES II, PLATES 3 AND 4 AND SERIES 1, PLATE 41

is still capable of feeling any doubt with regard to the correctness of our interpretation, he will surely be convinced that we are right if he will cast a glance at the three symbolic figures at the left of the engraving; the Serpent with its head turned to the left imitating almost exactly the position of the stars in this constellation: the two hounds, one of them standing and the other lying down (while the latter is less easily recognized his curling tail is unmistakable). This chart corresponds to the constellations visible in the sky from the 17th to the 21st of January; the choice among the signs is in large part identical with that of the picture previously examined, only the signs of the Zodiac being lacking.

A third map is found in Plate 41m of Baltzer's first series (Fig. 4). Here one may see the Fishes, the Dolphin, the Serpent, the Scorpion, the Archer, and the Fox (or possibly the Hound). The first four follow each other in correct order; the Archer and the Fox appear to be placed somewhat too far to the right, possibly in order to form a separate hunting scene. The constellations corresponding to these figures are found in the sky during the period from June 9th to July 11th. The presence of the Scorpion, an animal entirely unknown in Scandinavia appears to our mind a conclusive proof of the correctness of our interpretation of this symbolic design.

Plates 1 and 2, No. 6 of Series II, contain a man holding a horse surmounted by a group of dots in which it is easy to recognize the Auriga, the Charioteer, and Cassiopeia (Fig. 5). Plates 3 and 4, No. 15 of the same series probably represent the Milky Way, etc.

These engravings upon the rocks of Bohuslän have also enabled us to discover prehistoric celestial charts in Denmark.

The archaeologist, Henry Petersen, has described in his work entitled *Aarborger for nordisk Oldkyndighed* (Book of Art of Nordic Antiquities) which appeared in 1875, the astronomical symbols found in Denmark. His researches have proved that the images of the sun and the depressions in the form of a cup are found principally in North Zeeland, or more precisely in the region around Iselfjord. It is in this neighborhood, too, that the famous chariot of the sun of Trundholm and a large number of rock engravings representing the sun were found. This geographical distribution would seem to indicate a Scandinavian influence. Many of the carved rocks found in Denmark were discovered inside of megalithic tombs, and according to Henry Petersen they may have belonged to the Stone Age. Others, such as the two stones found at Ods Herred, bearing images of the sun and of boats probably belonged to the age of bronze, as do the Bohuslän carvings. We are of the opinion that we have discovered two celestial charts upon two stones found in megalithic tombs. These stones have no symbolic signs, like those of Tanum, but exhibit three series of three dots each like those in Fig. 3, corresponding probably to the lower part of the Great Bear. Furthermore, these two stones show the characteristic chariot. The stone of Venslev has above the Great Bear a single dot meant for the Polar Star, and still farther above two groups of dots which are less easy to identify, although one of them in the form of a square may be Cepheus and the other at Cassiopeia; to the right may be seen the characteristic symbol of Auriga. The Dalby stone (Fig. 7) is located on top of a dolmen. Thorkild Gravlund, who discovered these rock carvings, has already identified some of their dots with the Great Bear. The entire stellar figure is thus less clearly defined than upon the Venslev stone. However, it is possible to recognize the Lynx, the Lion, the Virgin, the Bull, with their characteristic stars. The position of the Great Bear and the Lynx with respect to each other is precisely right, as are likewise those of the Lion, the Virgin and the Bull; but the Great Bear and the Bull are much too far apart.

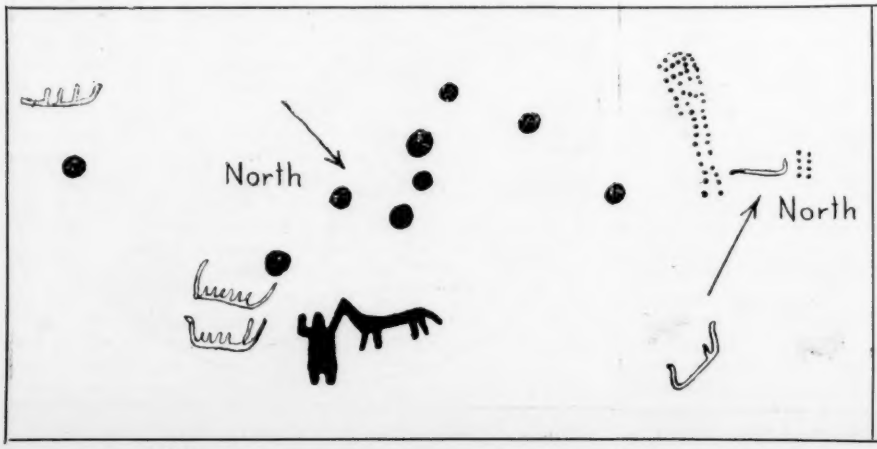


FIG. 5. ANOTHER OF THE ROCK CARVINGS AT BOHUSLÄN AFTER BALTZER, SERIES II, PLATES 1 AND 2

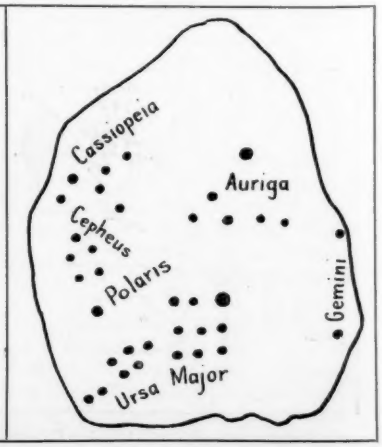


FIG. 6. CARVING AT VENSLEV, AFTER PETERSEN

It is worthy of remark that the most complete specimens among these rock carvings usually represent the skies at specially characteristic times during the year, such as the equinoxes and the summer solstice. This fact greatly augments their religious significance, and indicates their connection with the annual festivals. Furthermore, these astronomical studies may be explained by the fact that the stars already served to guide maritime commerce between the South and the North.

We can but wonder whether these carvings were made from memory or from sketches—for we must discard the third hypothesis, that the rock was carved at night from direct observation, since the work would then have been too difficult. Most of them are no more exact than might be expected if they were engraved from memory. However, at least one of them is so remarkably accurate that it is hard to believe that it could have been made without the help of a model. Possibly the artist made a model at night on a piece of wood and transferred the pattern to the stone by daylight.

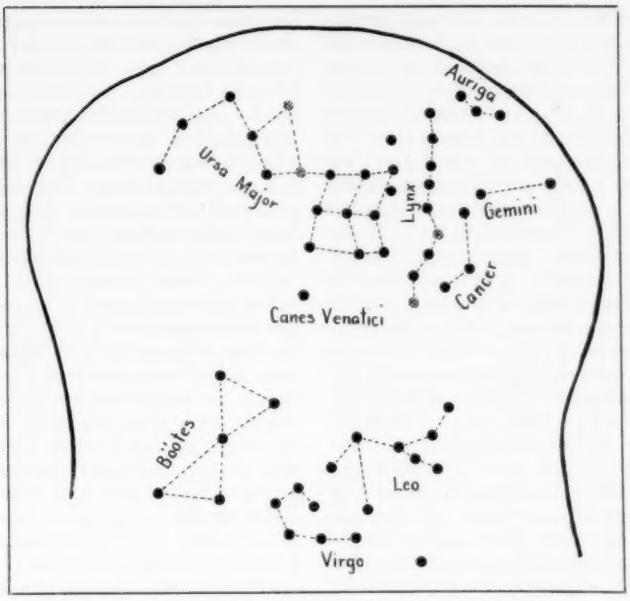


FIG. 7. ROCK CARVING AT DALBY, AFTER GRAVLUND

Skeptical critics will doubtless be found to declare that our theories are based on premises too slight; but certain Scandinavian archaeologists have already made an attempt to prove that even in the Stone Age direct maritime relations existed between the northern part of Jutland and the distant countries lying toward the south.

The present article does but little more than make a preliminary attack upon this very difficult problem, but we hope that this slight sketch will suffice to attract the attention of scientists competent to undertake the study of this engrossing enigma of the carvings upon the rocks of Scandinavia.

Tertiary Man in Flanders Fields*

Fossil Footprints That Show the Evolution of the Human Foot

By Professor W. Freudenberg

A FEW kilometers to the north of the Episcopal city, St. Niclas, an island of heavy clay arose ages ago from the late Tertiary waters of the North Sea at that time warmed by the Gulf Stream. The Scandinavian Peninsula was still united with Scotland by a bond of *terra firma*, forming a barrier against the cold winds and icy ocean currents of the north. The climate along the coasts of that ancient North Sea fed by the English Channel was at that time probably even warmer than it is today in the English Channel Islands and the Isle of Wight. Palms and bamboos spread their fronds luxuriantly upon the mainland through which roamed droves of a three-toed zebra-like horse. On the Isle of Sylt[1] on the eastern coast of this sea there has likewise been found a tooth of this wild horse, the *Hipparion gracile* and across the water, on the eastern coast of England, blessed at that time with a subtropical climate, there likewise lived droves of these same ancestors of the zebra as well as antelopes, gazelles and the most various kinds of thick-skinned animals, the rhinoceros and the elephant and even the mastodon. Thus we see that there actually existed an African fauna along the borders of the North Sea before the appearance of those masses of ice from the inland regions to the north, which brought with them their polar tribes of the musk deer, the Arctic fox, the woolly-haired mammoth and the Siberian rhinoceros.

But how long has it been, we may ask, since such a climate prevailed and such animals were seen along our northwest coast? If we reckon "the post-glacial period" with the coast outline and the climate of today at about 25,000 years, then the glacial period itself may be safely assumed to have lasted for half a million years. But the later Tertiary epoch up to the time that these herds of antelopes and zebras appeared upon the earth, lies fully a million years behind us.

HUMAN BEINGS OF THIS PERIOD

But now further questions arise in our minds: Did human beings exist at that time, and if so, what did they look like and what did they live upon? Is it not probable rather that they were intermediate forms somewhat like the *Pithecanthropus erectus* found in an early glacial stratum upon the island of Java? The data obtained from that remarkable find from the aforesaid little island in the delta of the mouth of the Pliocene Scheldt do not justify us perhaps in answering these questions with a positive affirmation; they are mere sign-posts but none the less worth noting. To begin with, let us inquire how it is possible for us to speak confidently of the existence of an island or a peninsula or even of a zone of shore in those ancient times, in a locality where there is today nothing but a flat and sandy plain. We should not be able to answer these questions without the aid of the spades and the drills of geologists. These men of science are able to recognize when and how the formation occurred of any sort of ground, whether its material be clay or sand or the moraines that mark a glacier's path. The degree of development of those sea mussels found in that sort of clay from the ocean bed gives to the geologist an indication of the time when this deposit occurred, and he may be helped in forming his estimates, moreover, by the fossils of the fishes or the drowned land animals,[2] which may chance to be found there also. In the case in hand there may have been mud deposited in the neighborhood of the coast, at a depth of about 100 meters, let us say, and this slime or mud may itself have become firm

*Translated for the *Scientific American Monthly* from *Die Umschau* (Frankfurt A. M.), for Dec. 11, 1920.

[1]This extremely valuable find, which was made in the micaceous clay of the Isle of Sylt, is preserved in the Museum of the Geological Institute at Hamburg.

[2]A small marsupial animal has recently been found in the Septarian clay at Antwerp.

land by reason of a retreat of the sea from the land at that point. The shore thus left dry would be changed in shape and outline at a much later period by the streams and the storms of the land. Thus there was formed a little circle of islands not unlike our Friesian Islands, but on a much smaller scale and with a partial connection of the islands with the solid land, like the islands of the delta of the Rhine. We must next suppose that through a sinking of the coast the sea surged up upon the land once more, after the ocean had reached its greatest depth. This happened, in fact, at the time when droves of three-toed horses were sweeping across the continent from China to Portugal, to Jutland, and to England, when a continental steppe climate spread over wide areas of the continent of Asia and Europe, accompanied by a similar spread of the fauna proper to such a climate. *It was at this time, according to our assumption, that man made his appearance.* His ancient tertiary and middle tertiary ancestors had been dwellers in subtropical forests. They belonged to a well-known race of anthropoid apes, we may believe, though this is not the proper place to discuss the mental qualities of those European anthropoids of Middle Tertiary times. Yet we may assume, I think, that matters stood thus with our corporeal ancestors if we admit that the intellectual life of man must be regarded as something of a peculiar nature and slow in development in relation to the race history of humanity. Let us inquire then as to what hypotheses may be suggested in these matters and what scientific conclusions it is possible to arrive at. As a geologist and a palaeo-biologist I am obliged to believe that these first members of the human race developed under external conditions such as those which have aided in the evolution of the most intellectual races of today. By this I mean that they were plainsmen—dwellers upon the open steppes. Here we have conditions highly favorable to the constant stimulus and consequent development of the functions of the brain of those anthropoidal ancestors of ours—creatures whose structure of body and degree of mentality resembled those of the great anthropoid apes—who had hitherto found their homes amid dense forests or in dark and narrow caves. For on the plains we have the open horizon with its implied demand for that estimation of distances which is a matter of such great importance to wayfarers across deserts or steppes, since an erroneous estimate all too frequently brings starvation in its train; here, too, man is vouchsafed the unhindered observation of the stars. It is evident that the vast sweep of the heavens above and the far-flung line of the horizon below tend to develop in the nomads of the plains and in the sons of the desert that power of measuring and reckoning—of calculation, in short—whose further evolution we observe in the seafarer and in the merchant.

Unsightly enough are the *footprints left behind him for our inspection by the Tertiary man at Hol by St. Gilles in Flanders.* These consist of impressions of the ball of the foot in which are plainly seen the marks of the papillary ridges and furrows—so clearly marked are these indeed after the lapse of a million years that they might attract not only the investigating eye of a studious anthropologist but that of a modern detective! Even the small toe has left its imprint—only half that of the fourth toe, however, is visible in the impression. This footprint, now hardened into stone, was once impressed in a lump of the tenacious Tertiary clay which formed the aforesaid shore or island and as the foot that made it strode away it was kicked off into the sands of the dunes. When, toward the end of the Tertiary period the Middle Pliocene North Sea flooded the islands of the Scheldt it spread over the clay which composed them the sediment borne in the raging waters. These imprints of human-looking toes hardened into solid stone and as such they remained upon the shore of the steadily southward spreading sea.

What was the creature who left these footmarks doing there? Was he really a man or merely one of a race of anthropoid apes, traces of which have already been found in the older Tertiary strata and which we recognize by their bony remains and their teeth? To begin with, while we may concede that these creatures were quadrupeds they were by no means ape like since the toe prints are all short—for that matter our own babies might be said to be quadrupeds at an early stage of their existence. How skilful the use an infant often makes of the soles of his feet and of his still mobile and unatrophied toes! And does not the fact that France has produced both a painter and a tapestry maker who, lacking hands, accomplished their work with their feet, offer proof enough that our Tertiary ancestors of a million years ago were four-footed creatures?

The anthropoid apes of today, the gibbon, orang-outang, and the chimpanzee with their many species and subspecies (in the case of the gibbon) all have long, climbing toes upon their feet: this is more marked among the apes of the East than among the anthropoid apes of the West, the chimpanzee and the gorilla, which possess the shortest toes by far among all the group of our nearest animal relations. This indicates that the foot is in these creatures not exclusively a climbing organ, but that they use rather the toes of the foot as a highly sensitive lever in order to balance the heavy body when in an upright position, just as human beings do when walking. We may conclude, therefore, that these toes which left their imprint so long ago in the late Tertiary coastal zone of Flanders, were constructed upon the same plan and for the same purpose.

Indicated Size of the Tertiary Man.—It is a striking circumstance that the toes which made these tracks were quite small. They correspond in size to those of a four-year-old boy, *hence they must have belonged to a pigmy less than one meter in height.* At the same time it is evident that the impression was made by the foot of an adult. A proof of this is found in the imprint made by the ball of the foot. In the young offspring both of human beings and of the anthropoid apes the tactile ridges and furrows upon the soles of the feet and the palms of the hand lie much closer together than in adults of the same race and sex as may be seen in Fig. 1. During the growth of the individual the skin and those small structures upon it which serve the function of touch become expanded. The ball of the foot of this prehistoric Tertiary man, assuming that it belongs to the same species as the aforesaid toes of human appearance, has the furrows of the tactile papillæ so far apart as to make it evident that the impression was made by an adult foot. The *curvature* of the impression of the ball of the foot, however, indicates plainly that its maker must have been less than one meter tall.

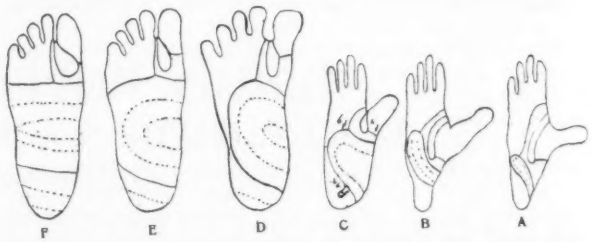


FIG. 1. SERIES OF DIAGRAMS SHOWING THE DEVELOPMENT OF THE SOLE OF THE HUMAN FOOT

A to C, the forerunners of mankind; D to F, the development of the foot from Tertiary man to the present time.

But we cannot avoid the belief that creatures of an anthropoidal nature and walking upright, must have moved about a good deal, even were they not driven by a genuine *wanderlust*, especially if we assume that the reason for the development of a foot so typically human in its aspect is to be attributed to the appearance of a climate like that of the steppes in Europe and Asia north of the Tertiary chain of mountains. The acquisition of such a foot could not have taken place amid dense primeval forests where both men and their rela-

tives, the anthropoid ape, must have remained as they were originally: chiefly tree-dwellers with feet adapted for climbing and with a more or less uncertain gait upon flat ground.

But the footprints of which we speak were found in the vicinity of the late Tertiary seashore. Possibly they were made in the miry ground of the delta at the mouth of the primeval Tertiary Scheldt, which appears especially probable in the case of the print made by the ball of the foot. The impress of the toes, which was found in the sandstone and was made therefore upon a sandy ground, was probably made also in the neighborhood of the sea—perhaps, likewise, on the shore itself—and then covered wiht a fresh layer of sand, which would account for the sharpness of its outline. Upon the under side of this imprint of the toes there is to be seen the impression made by a shell fish which suggests that this primeval man may have sought the shore to hunt for mussels.

A few kilometers to the east of the clay pit at Hol (St. Gilles), where the writer of these lines with the aid of some Belgian workmen, made the aforesaid find in the Tertiary sand-covering of the clay pit of a brickyard during the war, an excavation was made by the same workmen to the north of the locality of Vracene which afforded welcome support to the aforesaid hypothesis. We were digging in the same late Tertiary covering of sand as at Hol (where our discoveries were principally made), but in this new location the sea sand lay in a much thicker stratum above the clay, for the reason that we had left the vicinity of that ancient island of clay, and proceeded in the direction of Antwerp, where a much deeper sea prevailed during the geological epoch in question. This is evident in fact from the remarkable depth of the strata of sand in which the docks of Antwerp have been constructed. But in this locality, also, Septarian clay forms the foundation of the strata of sand. An enormous quantity of whale skeletons came to light during the building of the old harbors and among them were found also a number of the finely notched saw-like teeth, as big as a man's hand, of a giant shark whose present relatives (quite a bit smaller of size), make their home in tropical waters. Such teeth as these, with edges sharp as knives, were also found in our own excavations, especially at the point where the footprint was found, and these offer quite special proof of our thesis, since to all appearance these teeth were eagerly sought for by Tertiary man as valuable work tools, so that when these primitive creatures wandered shoreward they kept their eyes open, not only on the look-out for mussels to supplement their food and for bones and hints for utensils, but also for the huge shark teeth described above to assist them in opening the tightly-closed shells of the still living mussels which were part of their treasure trove. At first thought this may sound like a rather fantastic idea, but it is supported by the fact that one of our finds at Vracene was a number of mussels in the uppermost layer of the Tertiary mussel sand which had obviously been opened artificially by a sharp stroke or cut. As a *proof* that these mussel shells were really of tertiary origin and belonged, therefore, to the *preglacial era* we may note that those mussels which exhibited an incision of artificial origin (obviously intended to cut off the front muscle employed in closing the shell) belong to a species which is not only entirely extinct today but is lacking even in the diluvial strata of the glacial era. They are, in fact, the *Cyprina tunida*, a relative of the Iceland mussel.

Are we not, therefore, quite justified in regarding these ancient Netherlanders of those primeval times as true epicures, knowing how to appreciate oysters, as is proved by the numerous broken shells found at Vracene? We can, in fact, speak of piles of mussel shells, heaped up obviously by creatures more or less human in character along the aforetime borders of the Flemish North Sea, which today lie many kilometers inland by reason of the subsequent raising of the coast line during the glacial period. For there were also times during the glacial period in which the North Sea flowed farther to the south than is the case today.

Less illuminating as to their object than the incisions upon the two-shelled mussels are the regular curving strokes made upon the thick skull bones of an extinct species of whale. The idea suggests itself that some flexible material such as, perhaps, the skin of a seal, a walrus or sea cow (which at that time had not retreated toward the south) may have been rubbed against these grooved skull bones in order to rub off the fatty tissue clinging to it. This kind of manipulation would, of course, indicate quite a considerable degree of intelligence and skill. Often, too, they may have employed exceedingly sharp fragments of flint which are found among the deposit along tertiary shores. However, we cannot be quite sure of the artificial origin of these splinters of flint. All the more important is the discovery of what are *undoubtedly artificially shaped flinty stones* of the same period, *i.e.*, in the upper tertiary strata in the vicinity of Aurillac in southern France, by Professor Verworn of Bonn. We may assume, therefore, that tertiary man was clever enough successfully to shape tools from flint. This alone indicates a great step in advance over apes.

An Engraved Mussel Shell.—In the English Red Crag which is likewise a late tertiary shore formation, there has been found an engraved mussel shell upon whose convex side a human face has been crudely carved. It looks, to be sure, like the scratching of a child and yet this reddish stone still firmly retains the lines graved by this first exponent of the plastic art. There is a small hole bored through the "backbone" of the shell, so that the mussel could be worn as a pendant. To a period somewhat later at about the turning point between the tertiary and the diluvian, we find the *most ancient man upon English soil* in the form of the skull and the lower jaw of the *Eoanthropus*. The former exhibits external features more human in character but it contained the most primitive brain ever found in the skull of man. The lower jaw is quite ape-like with a shovel-shaped projecting snout. So different is its aspect from everything that we call human today, that it was at first thought by geologists to belong to a chimpanzee.

However, even today there are found in England men with lower jaws of a low degree of development—an inheritance, perhaps, from these primitive men. On the other hand the *most ancient middle-European ever found*, the *Homo Heidelbergensis*, exhibits purely human features in the form of the teeth together with a very remarkable, but not especially ape-like lower jaw. The third example of human remains likewise in the ancient quarternary was made in Java. This is the celebrated *Pithecanthropus erectus* whose upright carriage indicated by the thigh bone is combined with a very ape-like brain pan. Thus we have to discriminate between *three different species of primeval man at about the turning point of the tertiary period.* It seems probable that in other parts of the world, at about the same period of time there must have existed other markedly different forms of primeval man.

Instead of coming nearer to a common origin of man, as the ancient lore of church and school teaches us, and as even universities have been accustomed to hold, the farther we trace man back to a possible origin the more different in nature are the various races of man. Indeed there are *absolutely definite points of resemblance between certain races and the anthropoid ape.* According to our hypothesis we must regard human beings as correlated forms of evolution, as adaptations to a certain form of environment. The upright gait and the nobly arched skull must in the final analysis be regarded not as a common inheritance, but as a highly complex adaptation to the steppes or plains. To begin with, naturally, the region of the Asiatic steppes furnishes the original home of the modern sort of mankind, but it is also true that that realm of Europe which was transformed from a primeval forest into a great bare plain or steppe—particularly in the vicinity of the mountains with their numberless stimuli for the development of the human foot, must have been centers of creation for humankind.

Fish That Chew Their Cud

Confirmation of Aristotle's Claim That the Parrot Fish Should Be Classed as a Ruminant

As far back as the 4th century, B.C., Aristotle set it down as a curious fact in natural history that the parrot fish is to be classed among ruminant animals. This story was repeated by the Roman writer on natural history, Pliny. Both of these ancients doubtless had in mind the *Scarus cretensis* L., which was found more or less plentifully in the eastern part of the Mediterranean Sea. However, the story passed as a fable, like so many other ancient statements of fact since verified. These fish possess certain peculiar pocket-like extensions of the mucous membrane of the mouth, which serve like the cheeks of a squirrel or like two throat-pockets to hold food. A German writer, Dr. Fritz Reuter, gives a brief but entertaining account of these fish and their unusual habits of alimentation in *Kosmos* (Stuttgart) for November, 1920, from which we take the following paragraphs:

"The beak-formed jaws of the parrot fishes are covered with teeth, which are not only firmly attached to the jaw bone but also to each other. In young animals of some species the rows of teeth, which are arranged like the teeth of a comb, can still be clearly discerned. But in other species the fusion of the separate rows of teeth has proceeded further. In the *Scarus* and the *Pseudo-Scarus* the fusion has become so intimate that the original boundaries of the separate teeth can only be surmised from the rigid formation of the edges of the jaws.

But with these beak-like jaws the parrot fish can only bite off their food and not grind it, since the jaws are capable of no motion except a mere opening and shutting. Furthermore, the knife-like edges of the jaws are so sharp that they clearly indicate that the jaw plates are never employed as grinding teeth.

But besides these the lower throat bones which form the five branchial arches on each side are fused into an irregular plate which is covered with teeth of a peculiar form. This dentated plate projects distinctly above the surface of the surrounding mucous membrane. The very powerful upper bones of the gullet are attached in such a manner as to move back and forth in grooved hollows of the base of the skull; in consequence of this arrangement they are able to produce the grinding motion which, as we have seen, is impossible in the case of the toothed plates of the jaws. These bones bear three longitudinal rows of serviceable teeth, which correspond to the dentated plates of the lower throat bones. It is by the rubbing or grinding back and forth of these upper plates upon the lower ones that the vegetation which forms the fishes' food is ground into a very fine state.

The entrance to the cheek-pockets mentioned above lies very close to the lower dentated plate of the throat. Immediately behind the grinding plates the cavity of the jaws rapidly grows narrower, merging into the comparatively small gullet. As a matter of fact the contents of the stomach of the parrot fish are ground so finely as almost to form a sort of broth whose composition is very difficult to determine even with the microscope, so small are the particles which compose it.

Surrounding these cheek-pouches are strong muscular fibers forming a thickness swelling of the mucous membrane, whose contraction forces the bitten off food farther to the rear. In front of the upper gullet plate the mucous membrane forms a thick fold corresponding to the swelling of the lower part of the gullet mentioned above. This fold is probably intended to press the bitten off pieces of food into the cheek pouches.

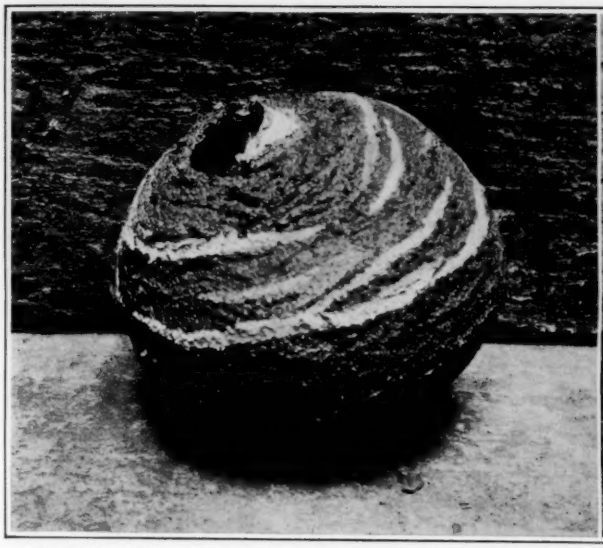
The content of the pouches, *i.e.*, the nutriment of the fish, consists chiefly of algae, but also contains bitten off pieces of hydroid polyps and prongs of silicious sponges, as well as fragments of corals. All these bits of food in the pouches are found in small pieces but by no means reduced to the broth-like fineness of the contents of the stomach. As a matter of fact an actual process of "chewing the cud" takes place in these fishes. With their sharp jaw teeth, working up and down like a pair of shears, they bite off from the rocks of the coral reefs, in whose vicinity they live, pieces of food material. The steady current in the water produced by their respiration facilitates the rearward movement of these bitten off pieces of food material. A sort of valve arrangement prevents these from reaching the gills, and by the contraction of the muscles in the swollen mucous membrane they are forced into the cheek pouches. Later when the fish has grazed sufficiently, so to speak, in these meadows of algae, it seeks a quieter place in order to be undisturbed in its digestion, and at this time the contraction of the pouches forces the food they contain back into the mouth cavity, where it is chewed fine in peace and quiet—exactly as is the case in the chewing of the cud of our domestic cattle. In other words the regurgitated food in the mouth is ground or rubbed into a liquid condition between the upper and lower grinding plates. When the fish is at rest this grinding motion can be plainly observed, and it was this without doubt which led the ancient authorities mentioned above to make their happy comparison of this process with the chewing of the cud in domestic ruminants.

The magnificent colors of these fish are familiar to visitors in all our great aquariums—colors which quickly fade when they are taken out of the water. They have been celebrated, too, from the earliest times for their appetizing qualities as food fishes. Pliny even declared that this fish was the choicest dainty of all. . . . On account of this delicacy of flavor the Emperor Claudius took special steps to transplant these fish from their original homes along the eastern shores of the Mediterranean to the west coast of Italy, decreeing that for a period of five years all the parrot fish caught in these waters should be thrown back into the sea, by the end of which time they were well established in their new habitat.

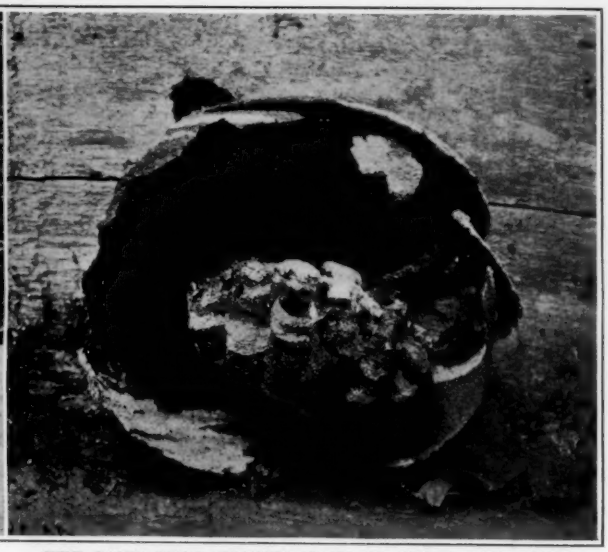
THE EFFECT OF LIGHT ON SO-CALLED EYELESS ANIMALS

Some curious and instructive experiments have recently been made by Prof. Paul Kammerer, of the Biological Institute of Vienna. This institute possesses a very deep cistern and it was found that the salamander born in this cistern differed from the parents only through a smaller size and through their plainly recognizable eyes, which were visible through the thin skin covering them, resembling poppy seeds. One of these animals was exposed to light and the consequences were noteworthy. The hitherto colorless skin turned black and the eye also regained the usual dark color. On this account a ray of light must be chosen which contains no color. For this reason a red lamp was employed. One animal was exposed to this light for five years and five animals were exposed alternately to the red light and to daylight. In the latter five animals a formation of pigment was clearly seen which, however, was not sufficient to cover the eye. In the ordinary cave-living salamander as it increases in age there is a disappearance of the cell of the cellular lens, but in the animals exposed to light, as above described, the eye was eighteen times as long and twelve times as broad. The skin was found to have become extremely thin over the eye, a regular pupil and iris being visible.

By tests made with proper food it was found that these animals were quite well able to see. These experiments plainly show that the ancestors of the so-called eyeless cave fish possessed eyes which gradually became atrophied through their changed conditions of life, but whose rudiments are still possessed and can be made to develop.



THE NEST OF A HORNET SHOWING ITS THIN PAPER-LIKE ENVELOPE



THE SAME NEST BROKEN OPEN TO SHOW THE CELLS WITHIN

Hornets and Other Social Wasps

Nest Building and Community Life Among the Vespidae

ONLY less fascinating as a subject of study than their close relatives the ants and the bees are the wasps, whether the true wasps which like ants and bees are citizens of highly organized social communities or the so-called solitary wasps. As John Burroughs has remarked this study "opens up a world of Lilliput right at our feet, wherein the little people amuse and delight us with their curious human foibles and whimsicalities and surprise us with their intelligence and individuality."

All of the true wasps belong to the *Diploptera*, a division of the suborder *Aculeata* in the order of the *Hymenoptera*. The *Diploptera*, which comprises more than 1,000 different species may be conveniently subdivided into two groups, according to their habits of life. One of these is the *Vespidæ* which includes all the social wasps, including the hornet or *Vespa crabro* and the common wasp or *Vespa vulgaris*. The other group contains the solitary wasps, the *Eumenidæ* and the *Masaridæ*.

The social wasps greatly resemble bees in their manner of living, their communities consisting of males, females, and neuters or workers. However, the community is not perennial like that of the bee but merely annual. Most of the colony perishes when summer passes but a few females which have been mated take refuge in sheltered places, such as hollow trees or overhanging rocks and hibernate till the following spring. When such a female is roused from her torpor by the balmy airs of the warm season she comes out from her castle of refuge and at once sets about her business in life of founding a new colony.

The common wasp usually selects a hole in the ground enlarging it to suit her needs; she then begins to build her nest. For this purpose she gnaws off bits of wood from convenient sources and "chews" these into a sort of pulp mixed with saliva, until she has a mass much resembling the "spit balls" with which naughty boys sometimes enlivened the schoolroom of our childhood days. This sort of natural *papier mâché* is the wasps' building material. Some of it is shaped into a hanging pillar—a sort of stalactite hanging from the roof of the chosen cavity. In the lower free end of this column, three shallow cup-shaped cells are hung, and in each of these an egg is laid. The capable builder of the colony now continues to add new cells, placing in each the appointed egg. Meanwhile the first-laid eggs soon hatch into grubs and the busy mother must add to her labors by feeding and tending her offspring.

The grubs are oddly shaped little creatures, being thicker in the middle than at the two ends. They are suspended in their cells head downward, and they give their fond mother a considerable amount of trouble, for she first carefully chews the insects which form the usual *piéce de resistance* of their diet. Since all this time the mother wasp is adding new cells, her work is obviously "cut out" for her. It takes about eight days for an egg to hatch and the grub must be fed for a couple of weeks longer, after which it spins a silky cover to its cell and becomes a pupa, emerging as a perfect insect at the end of ten days more. The new-born insect either pushes the cover out with its head or bores a round hole through it. And now another task awaits the thrifty housewife; while her offspring flies gaily off to seek its fortune in the world, the mother carefully cleans out the apartment just vacated and lays a fresh egg in it, so that sometimes the same cell has several lodgers during the summer. However, the mother is assisted in her herculean labors by her first born offspring, since these are all neuters and are set promptly to work in caring for the home, enlarging the comb, and feeding their younger brothers and sisters.

The fact that only workers appear during the first half of the summer is probably connected with the greater scarcity of food at that time. As fruit begins to ripen on the trees and spread its largess to the insect world, food becomes more abundant, and fully developed females and males emerge; these are larger than the workers and, therefore, require larger cells for their development. They are usually kept apart from each other and from the workers. Strange to say the males develop from non-fertilized eggs laid by the later broods of workers and developed through parthenogenesis. They have no stings and may be distinguished by their more slender bodies and their longer antennæ.

In a good season when the sun is kind and the harvest abundant, a single nest may contain several thousand cells full of wasps in various stages of development, since each cell is occupied two or three times some authorities estimate that

a single community may comprise 30,000 insects. The combs are arranged horizontally, and contain a single layer of cells, opening downward. The second comb is suspended from the first by a number of hanging pillars which are built from the point of union of three cells. The space between two combs is just sufficient to allow the wasps to cross each other. The combs are roughly circular in outline, and increase in

A NEST OPENED TO SHOW ITS FORMATION

size for the first four or five layers, after which they begin to decrease; the whole is covered by a roughly made coating of the same papery substance which composes the combs. This at first forms a cap-shaped protection, but as each comb is built it is continued down until finally it forms a roughly spherical covering for the whole, but not giving any support to the combs, which are independent of it. The covering is pierced by apertures for the passage of the wasps. The cells are hexagonal at their mouths, but above become more rounded in their cross-section.

HORNETS (*Vespa Crabro*)

While not all wasps are hornets all hornets are wasps. They are larger in size than a common wasp and more reddish in color. They may be distinguished also by the row of red spots on each side of the abdomen.

Their nests resemble those described above, but are larger; they are found in hollow trees or deserted outhouses. Their communities are smaller in number than those of common wasps.

The hornet where it occurs in any number does a considerable amount of damage to forest trees, by gnawing the bark off the younger branches to obtain material for reconstructing its nest. It usually selects the ash or alder, but sometimes attacks the lime, birch and willow. Like the wasp it does much damage to fruit, upon the juice of which it lives. On the other hand, the wasp is useful by keeping down the number of flies and other insects. It catches these in large numbers, killing them with its jaws and not with its sting. It then tears off the legs and wings, and bears the body back to the nest as food for the larvæ. Wasps also act to some extent as flower fertilizers, but in this respect they cannot compare with bees; they visit fewer flowers and have no adaptations on their legs for carrying off the pollen.

The genus *Vespa* is very widely spread; it contains over forty species, distributed all over the world. Some of the largest and handsomest come from eastern Asia. *V. mandarina* of China and Japan, and *V. magnifica* of the East Indies and Nepal, measure 2 inches across the wings; *V. orientalis*, found in Greece, Egypt, and the East, builds its nest of clay.

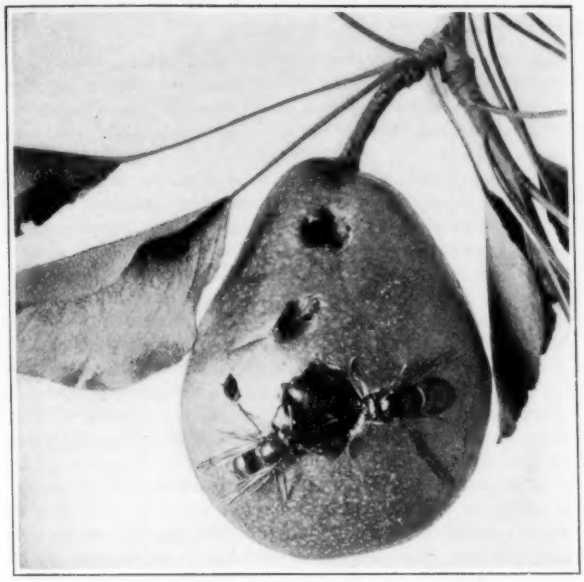
The only other genus of *Vespidæ* which is found in Europe is *Polistes* which occurs in the countries bordering the Mediterranean. The colonies of this genus are much smaller than those of *Vespa*. Each nest consists of a single tier of cells in the form of a round plate, supported in the middle by a single stalk. This comb is sometimes vertical, the cells then being horizontal or slightly oblique. Some of the members of this genus store up honey, which in the case of a South American species is poisonous, from the nature of the flowers from which it is gathered. The members of this genus have a slender body; the thorax is more oblong than in the genus *Vespa*, the palps stouter, and the abdomen more distinctly peduneulate.

The hornet, known to European naturalists as the *Vespa Crabro*, is known in this country, where it found a habitat many years ago, becoming Americanized with much less difficulty than some of our emigrants. Is more generally known in this country as the *Vespa maculata* among naturalists. It is sometimes popularly called the white-faced hornet, since the head is marked with white, while the body is black. It is the largest and fiercest of all wasps—many people, by the way, may be surprised to learn that it really is a wasp, since its body has none of the slender elegance, which has made the term "wasp waist" a proverbial expression. It is very irascible and its sting inflicts a really painful wound. Moreover, it will pursue those who meddle with its nest, whether purposely or accidentally, for long distances. A friend of the writer declares that he discovered when a boy that the only way to escape one of these insects when angry was by suddenly hiding behind a bush or a tree, whereupon the hornet appears to be baffled. One of our illustrations shows a fight between a hornet and a bee, in which the former appears to be getting the best of it. Some of them, by the way, not content with attacking ripe fruit for its sweet juices, do not hesitate to kill bees and rob their hives of its honey.

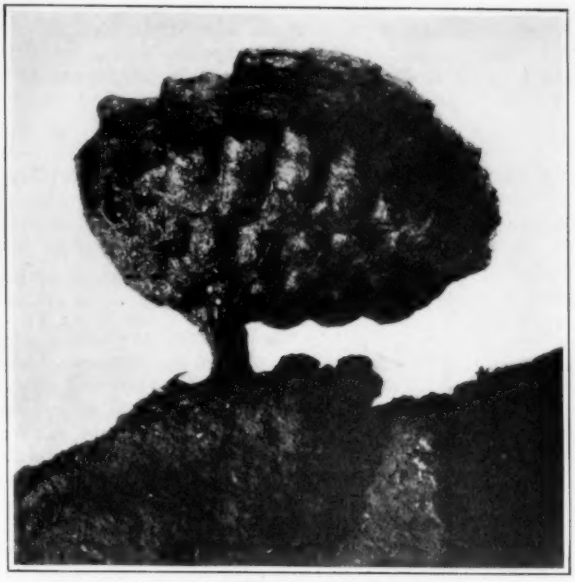
While the name yellow-jacket is rather indiscriminately

A HORNET (*VESPA CRABRO*) ATTACKING A COMMON BEE

THE *POLISTA* WHICH BUILDS ITS NESTS WITHOUT AN ENVELOPE



WASPS SUCKING THE JUICE OF A PEAR



THE HANGING COVERLESS NEST OF THE *POLISTA*

applied to any wasp marked with yellow, even including the hornet, it is usually applied in America to the common wasp *Vespa vulgaria*.

MATERIALS OF THE NEST

A very notable feature in the building of wasps' nests is the neatness they observe. When the cavity in the ground has to be made larger, which is very often the case, the particles of earth excavated are not merely dropped outside but carefully picked up in the mandibles of the insect and carried to a considerable distance. Since the earth thus excavated is spread over a very wide area, it leaves no trace of the locality of the nest. The paper pulp produced by the wasp's mastication of wood, or sometimes of scraps of paper or pasteboard, soon dries into a sort of brown paper, streaked with paler bands according to the nature of the wood employed. Thin as this paper is, it keeps the brood warm enough to hatch because of the method in which the nest is made. The latter consists of broad overlapping scales arranged in numerous layers. These hold air between them so that the finished structure which holds the eggs and infant creatures keeps them as warm as a "bug in a rug." Fabre declares, indeed, that when the weather is hot the temperature must be actually tropical within these apparently flimsy shelters.

When the colony is considerably advanced so that there are a number of disused cells the workers attack these and reduce them to pulp to be used in the manufacture of new cells. They prefer, indeed, to work over this old material since their task is easier than with fresh wood.

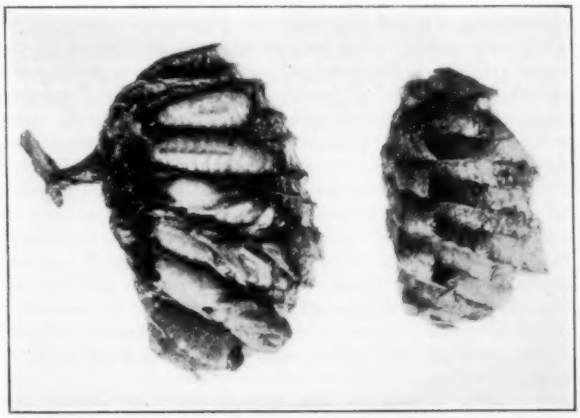
METHOD OF FEEDING THE YOUNG

The larvæ are blind and like human babies they spend much of their time in sleep. When their mother or nurse arrives at the door of the cell she, therefore, wakes the grub with the tip of the antenna, whereupon the infant gapes greedily, like a young bird at the sight of a worm. Being blind, however, the larva must swing its head about a bit in order to find the nurse's mouth and receive a drop of nourishment. In the process of transferring the ration, the larva often fails to receive the full amount in its mouth, but nature has provided against waste by a very accommodating arrangement. When the grub is receiving its food its neck swells so as to catch any escaping particle, like a broad napkin spread over the chest of some bucolic trencher-man. These precious drippings are neatly licked off by the infant grub whereupon the swelling recedes.

While the etymology of the word *hornet* is rather uncertain it appears to signify the horn bearer—thus we have in Old Low German the equivalent *horn-beron*. However, authorities differ as to whether the reference is to the antennæ, which project like horns, or to the buzzing noise made by the insect, which might be fancifully compared to that made by a trumpeter or "horn-bearer." The sound is certainly sufficient to strike terror to the heart of any unlucky wight who has had the misfortune to "bring a hornet's nest about his ears"—a phrase by the way which has become proverbial in its figurative sense.

RUTHLESSNESS OF WASPS

In spite of the remarkable social instincts of wasps—or shall we say because of them—they seem lacking both in intellect and the higher emotions thus, a wasp mother is said to ruthlessly put to death any of her offspring which she



NEST OF *POLISTA* SHOWING THE TRANSFORMATION OF GRUBS INTO NYMPHS

finds unduly feeble or deformed. Mr. and Mrs. Peckham, who have devoted much time to the study of wasps, give an account of several interesting experiments to prove this point: Thus, they killed a number of wasps and placed them near the nest; their surviving relatives displayed neither grief nor alarm, but at once set about cutting up the bodies by way of a convenient food supply for the youngsters! Again, these observers placed some tempting dainties at a distance from the

nest, to see whether the first discoverers of the repast would spread the glad news as ants are in the habit of doing. Not so! The first two or three who happened to chance on the booty would fly back and forth all day, keeping the secret of their treasure trove to themselves.

VESPA ARBORASTORUM OR TREE LIVING WASPS

While common wasps and a closely related species *Vespa Germanica* which is likewise found in this country as well as in Europe, build their nests in an underground cavity, the small wasps known as the *Vespa arborastorum* suspend their nests from trees.

POLISTA GALLICA L.

Some of our illustrations show another interesting wasp, the *Polista*. This insect is from 12 to 16 mm. in length, having a black body with numerous yellow spots or marks. A characteristic feature of their nests is that there is no external envelope such as described above as covering the nests of other social wasps. Usually the nest consists of a simple row of cells with which a second row is connected by means of columns. As in the case of other wasps' nests the cells are hexagonal in shape and consist of sort of brown paper; a large pedicle attaches them to the chosen support and this is always selected in a warm locality which explains the lack of a covering. As our picture shows this curious construction of the nest makes it look not unlike an inverted mushroom.

FOOD OF ADULTS AND LARVAE

While the larvæ of wasps are said to be chiefly if not entirely carnivorous in their diet, though Fabre successfully fed them with honey in some of his experiments, the adult insects have a very pronounced "sweet tooth," if the expression is permissible. They are very fond of sugar as well as of honey and sweet juices, and many a housewife has been annoyed by their enthusiastic and determined forays into her kitchen, when she was making preserves.

When they find a supply of sweetmeats or other attractive dainties at a considerable distance from the nest, wasps pay little attention to other insects likewise attracted to the feast, but when the banquet is spread near their own nest, they at once sit up and take notice, so to speak. They warn the intruders off at first gently and amiably enough, by a blow of the legs, but if the unwelcome guests neglect to take the hint and especially if they approach too near the nest, whether drawn by greed or curiosity, or merely through ignorance, they are immediately killed and thrown to the bottom of the excavation in the earth, which is, in fact, an actual slaughter house, wherein are thrown not only such victims but malformed larvæ and eggs which have failed to hatch properly.

There is one curious exception to this stern law of death to intruders, and this is practised, not by way of hospitality, but merely as an economic convenience as it were. The *Volucella* is a large fly which is permitted to lay its eggs in the nest, where their larvæ, when they emerge, act the part of scavengers, disposing of the refuse produced by the excreta of the wasp larvæ. These fly larvæ crawl in behind each wasp pupa and collect the dejecta which otherwise might make the nest unsanitary.

While flies, worms, etc., are captured and masticated to serve as a sort of predigested food for the larvæ, wasps also eagerly enter butchers' shops where meat is exposed and cut off bits of it to carry home. Some species such as the sphex also paralyze caterpillars, so as to furnish a supply of living though torpid food for their offspring. (See SCIENTIFIC AMERICAN MONTHLY for November, 1920, p. 222.) Some wasps attack spiders, mutilating the bodies if necessary in order to carry them conveniently to the larder. Others rather specialize on grasshoppers, and these, of course, are real friends of the farmer, more than repaying him for their minor thefts of food or honey.

THE UPWARD TRANSLOCATION OF FOODS IN WOODY PLANTS

IN the *American Journal of Botany* for July, 1920, Dr. Otis F. Curtis of the Laboratory of Plant Physiology of Cornell University gives an account of experiments made to determine whether or not there is an upward translocation of foods in woody plants.

In one group of experiments large numbers of twigs and branches were ringed early in the spring while the buds were still dormant or were just beginning growth. These rings were made at different distances from the tip in order to determine from how far back food was withdrawn for shoot growth. Since, as was shown in a previous paper of the author's, no appreciable upward movement of foods occurs through the xylem, the growth of a shoot above such rings should serve as an approximate measure of the amount of food available. If the ring were back far enough from the growing tip to allow for growth practically as great as that on unringed twigs, it would seem that these twigs need not draw on the food stored at greater distances.

A large number of stems of *Acer saccharum* were ringed on April 5 at different distances from the tips. In one series the rings were in the first-year wood, in another in the second- or third-year wood, and in another the rings were in that part of the stem ranging from five to fifteen years old. Some of the stems had made terminal growths in the previous year of from only 10 to 20 centimeters, while others had made growths of from 20 to 40 centimeters. In each case a check stem was chosen as nearly matching the ringed one as possible. The check and ringed stems were usually the two terminals of a pair produced by dichotomous branching.

Of 15 twigs ringed in the one-year-old wood, the average terminal growth on May 6 was 0.84 cm. That of the corresponding stems not ringed was 2.22 cm. Of those ringed in the two- and three-year-old wood the average terminal growth was 2.03 cm., while that of the corresponding checks was 2.25 cm. The leaves of the ringed stems in these cases did not show the bronze tinges that were common in the normal young leaves, but were a bright green. At the same date, May 6, there were no apparent differences in the growths of stems not ringed and of those ringed back on the 5- to 15-year-old stems. On May 25 measurements were made of these stems. An average of the shoots of ten stems of this series showed a growth of 9.96 cm., while that of the corresponding check stems was 11.09 cm. The older stems, whether the diameter was large or small, showed growth fully as great as that of those not ringed, but some of the younger stems showed somewhat lessened growth which lowered the average for the growth of ringed stems. In most cases growth had ceased and terminal buds were beginning to develop at the time of measuring. In another experiment a number of stems of a pear tree growing in sod were ringed. These stems ringed in the one- and two-year-old wood showed distinctly lessened shoot growth, but those ringed where the diameter was from 1.5 to 3 cm. showed growth fully as great as that of the unringed stems.

The data collected from these and other experiments show that shoot growth is fairly vigorous when no food further back than that obtained from a branch about one centimeter in diameter is available, and that when the ring is no further back than the 5- to 10-year-old wood, the growth of the shoots above the ring approaches more and more nearly that of the unringed stems.

Discussing his results, Dr. Curtis says that even if one could use large numbers of uniform stems that have been grown under uniform conditions, it would be difficult to determine from ringing experiments alone as to the exact distance of upward movement, for a check in growth may result not from lack of food but from lack of water due to the fact that no new xylem would be formed in the region of the ring, because in some trees much of the water may be carried through this new xylem.

Why Roots Grow Downward*

The Modern Statolithic Theory of the Geotropic Action of Roots

By Hermann Van Guttenberg, Berlin-Dahlem

SOME twenty years ago there appeared in the *Reports of the German Botanical Society* two articles, which attracted widespread attention not only among the professional botanists but among laymen. These articles contained the first statement of the so-called statholithic theory of the geotropism of plants. The two well-known botanists, G. Haberlandt and N. Nemec, had arrived quite independently at the common conclusion that the sensation of position in plants and the twisting motions dependent thereupon—in brief their geotropism or earthward turning—might be explained by the capacity for alteration of location possessed by certain bodies contained in the cells, just as the sensitiveness to position of animal organisms is explained by the theory of the so-called "statoliths" located in the statocysts, which constantly follow the pole of gravitation. Twenty years is no inconsiderable period in the realm of modern scientific investigation, hence it may be well worth while to undertake a brief examination of this theory to see how it has "stood up" under the test of time. Let us begin with a brief statement of the features of the theory. The idea that there might be found formations in plants analogous to the statocysts discovered in plants was first suggested by Mall in his work entitled *Concerning Heterogeneous Induction* (Leipsic, 1892), and *concerning geotropism* (Yearbook of Scientific Botany, 1900). Since, however, he had no exact knowledge concerning such bodies, he assumed the existence of minute invisible bodies, which he called "centrosomes" present in so-called "centrospheres" and assumed that the location of the hypothetical bodies was in the quiescent external plasma skin—meanwhile Haberlandt and Nemec made the discovery that there actually exists in the cells of plants certain bodies which are capable of changing their position, and a systematic investigation of these soon showed that such bodies are regularly found in certain plant tissues. Above all they noted that the starch grains contained in leucoplasts or chloroplasts very generally possess a greater specific gravity than that of the surrounding plasma fluid, as a result of which they sink. Any inclination of the plant organ containing them occurs at once to that portion of the cell wall which has, for the moment, the lowest position. Besides these starch grains there are also found crystals and cell nuclei which are capable of changing their position upon occasion.

Now, if we assume that the motionless external plasma skin is sensitive to the pressure of the "statolithic" starch grains we have at once a very simple explanation of the manner in which plants are able to perceive the direction of the pole of gravity, and how they can be acted upon by gravitation as a stimulus. For it is obvious that various portions of the plasma skin will be subjected to the pressure of the starch grain according to the manner of inclination of the plant organ, and a definite position of the starch grains will correspond to the normal position of the portion of the plant in question.

The advocates of this theory were able to prove to begin with that all of the higher plant forms possess such arrangements, and that at the very locations in which the stimulus of gravity is perceived. This becomes especially significant where a strictly localized geotropic sensitiveness exhibits itself as in the extreme point of the roots and in the points of the cotyledon sheaths. In the first case there is the heaping up of movable starch grains in the cap of the root, while in the latter case this heaping up is found in the spatulate portion of the point. In the stem organs such starch grains are found in the sheath of starch surrounding the circle of vascular bundles in plants whose stems are divided by so-called nodesas, for example, in the grasses.

It was soon agreed that this theory was in perfect harmony with the anatomical and psychological data at hand. And nothing has occurred to change this opinion up to the present time, since the very latest facts learned by observation agree most admirably with the demands of the theory. When the opponents of the theory, however, pointed out that in many of the geotropically sensitive fungi no one has, as yet, found analogous bodies capable of altering their location, the only answer to their objections was that we are also familiar with certain lower animals who exhibit a sensitive reaction to position in spite of the fact that they possess no statocysts —yet thus far this fact has induced no one to deny the importance of the statocysts in other animals. . . . Kreidel has shown in fact that there are certain *Garnelen* which, instead of the usual statoliths, contain particles of iron in their statocysts and, consequently, react not only to the force of gravity but to that of magnetism.

RESEARCHES UNDERTAKEN IN SUPPORT OF THIS THEORY

Various attempts were made to produce evidences either for or against this theory by the removal of the statolithic starch grains. This proves to be very difficult, however, since it has been found that plants retain an extraordinarily tenacious hold upon this starch, which very fact indicates that the said starch grains cannot be regarded merely as reserve stores. When the said attempts were finally successful, however, and the disappearance of the starch was occasioned by such methods as starvation, the raising or lowering of the temperature, treatment of certain chemicals, etc., yet the objection could not be answered that the absence of geotropic twistings was due not merely to the loss of the starch but to a general injurious action upon the plant. This was even more true of those experiments in which the starch providing portions were removed by means of the cutting out. Very recently a new investigator, Clara Vollikofer, has described a method for the removal of the starch of geotropically sensitive organs, which completely avoid any injury to the plants. She accomplished this by first cultivating embryo plants in the light for not too long a time, under normal conditions and, then placing them in the dark for a few days, thus causing the statolithic starch grains to disappear before the capacity for growth was exhausted. She employed for her studies embryos of the *Compositæ*, especially *Tagetes erecta* and *Dimorphotheca aurantiaca*, since in both of these the starch sheath of the hypocotyledons contains very little starch to begin with. The plants were allowed to grow in the light from two to four days and then were placed in the dark. After the lapse of one or two days a marked diminution of starch grains with respect to both number and size became evident, while after the lapse of three or four days embryos of Tagetes Dimorphothrea and Calembula (the latter after a partial removal of the cotyledons) had entirely lost their starch. Embryos of the Helianthus lost their starch at the end of five or six days, but in the case of these plants it was necessary to entirely remove the cotyledons because of their very high content of starch. Since the plants were first raised in the light they exhibited very slight appearances of etiolation or even none at all. In order to measure the amount of growth during the period of geotropic stimulation India ink marks were placed beneath the cotyledons; furthermore, in order to indicate with precision extremely slight twistings very fine glass pins were attached to the upper end of the hypo-cotyledon by means of a drop of plaster of paris. After such a preparation the

*Translated for the *Scientific American Monthly* from *Die Naturwissenschaften* (Berlin), July 16, 1920.

plants which had been more or less deprived of their starch by this method were placed in a horizontal position for twenty-four hours, in order to determine whether they had retained or lost their capacity for geotropic twistings.

The results showed a close agreement between the content of starch and the appearance of geotropic twistings. Out of 397 Tagetes seedlings 48 showed geotropic twistings; 42 of these still contained statolithic starch grains, whereas in the remaining six examples no residue of starch could be found. The other 349 plants had lost their power of making geotropic curves although 271 of these exhibited considerable growth and, therefore, would have been able to make the geotropic curves had they received the proper stimulus. Expressed in percentages only 1.5 per cent of the seedlings as we see failed to correspond with the requirements of the theory. In the case of the *Dimorphotheca* in which scarcely a trace of starch was left, only three out of 201 plants displayed the geotropic curves and two of these did so without any perceptible starch grains. In the *Helianthus annuus and Calendula, Officinalis* this error amounted to only 1.2 per cent, while it was lacking entirely in *Helianthus multiflorus*.

In order to find out whether even this process was not slightly injurious some of the plants were brought again to the light, after being in the dark. In the Tagetes half of them exhibited reaction within 36 hours while in 48 hours all the plants were again strongly geotropic. At the same time the statolithic starch in the sheath had been regenerated. The same result was obtained in the *Dimorphotheca* in 3 or 4 days. The *Helianthus* seedlings which had been robbed of their cotyledon were naturally unable to recover merely through restoration to the light, but numbers of them succeeded in regenerating a part of their starch when they received a special food in form of grape sugar. Such plants as a rule also proceeded to execute feeble geotropic movments.

Sensitiveness of the Plasma.—In order to test the sensitiveness of a plasma at the time of the loss of starch a number of test plants were also excited *phototropically* by being exposed to the light on only one side. In order to exclude the possibility of a new formation of starch the seedlings were placed during this illumination in air deprived of carbon dioxide. Of 189 Tagetes plant tested in this manner 36 ceased growing. Of the remaining 153, 148 clearly exhibited phototropic curves. Similar percentages were found in the cases of other plants. This clearly proves that the plants which have lost their starch are still quite capable of curving in response to excitation and that the plasma has retained its sensitiveness to excitation by light. But this makes it very probable that the failure of geotropic curve depends neither upon the capacity for reaction nor the non-sensitiveness of the plasma. It seems far more probable that this failure to react of the seedlings is due to the lack of another primary factor in the chain of stimuli, and nothing is more plausible than that it is the lack of the starch grains which is responsible and to regard these as the transmitters of pressure...

Less convincing than the foregoing are experiments of Zollikofer regarding the cotyledon sheaths of grasses. These organs possess as we have said an abundant supply of movable starch grains in their points which are extremely sensitive geotropically. Fraulein Zollikofer found that these starch grains disappear at approximately the same rate that the geotropic power of curving vanishes. Since, however, on the one hand the breaking up of the starch is far from complete, while on the other hand a new factor makes its appearance in the piercing of the sheath by the young foliage leaves the relation between the two things is here hardly so clear.

Fraulein Zollikofer also discusses a theory proposed some years ago (1907) by Linsbauer, in a study concerning the growth and the geotropism of the aroid air roots. He tried to prove that it was possible for geoperception to be exhibited without any means of pressure transference. He had the idea that in the plasma itself netlike structures might undergo, under influence of gravity, alterations of form or at least of tension and that in this manner the plant might possess a perception of the stimulus of gravity. It can be admitted at once that such a concept is entirely supportable but it has the disadvantage *a priori* that it is incapable of observation and probably also of being tested by experiment. Fr. Zollikofer is quite right in laying stress further on the fact that the latest researches concerning the so-called *foam* structure of protoplasm regard such a network as consisting of a foam produced by two fluids which are non-mixable or only slightly so, and that such a foam must be regarded as possessing a comparatively stable structure by reason of its foam tension; a structure thus stable could hardly be altered by a mere change of position of the organ.

"TRAVELING" TIME

Let us now examine into whether and how far experiments with geotrophism support the statolithic theory. The time required for the change of place of the starch grains in the cells (the so-called "traveling" time) amounts usually to from 5 to 20 minutes. This agrees quite nearly with the fact that the briefest time during which a plant must be excited in order subsequently to accomplish even one curve (the so-called "presentation time") is about equal in length. But Fitting has shown that plants also perceive stimuli of less than one second's duration. This has been proved by the fact that it is possible to produce a geotropic curve by the cumulative result of such brief stimuli. Fitting also discovered that plants which are subjected to the geotropic stimulus alternately on different sides—for instance, they may be placed in a horizontal position and then after a revolution of 180° exposed in a smaller or greater angle of inclination constantly occur in the direction of the horizontal stimulus. This results again from the cumulation of the separate stimuli and this cumulative result is obtained even when the separate times of exposure are extremely short. In this and other instances the curving is supposed to occur without a gathering to one side of the starch grain. L. Jost, furthermore, observed curves in the roots and cotyledon sheaths of lentil plants which had been subjected for two or three hours to the effect of a centrifugal force amounting to 0.02-0.05 gr. without any one-sided assembling of the starch grains having appeared.

In 1918 J. Buder published his researches upon the statolithic hypothesis during which he made a precise test of the distribution of the starch under similar experimental conditions. These studies led to results essentially more favorable to the support of the statolithic theory. On the one hand he proved that there is a "traveling" or change of the starch which takes place by the combination of various angles of deviation and, furthermore, he proved that even when there was a very feeble centrifugal force applied (about 0.13 gr.) a one-sided settling of the starch occurred. In a case of slight application of centrifugal force the starch grains distributed themselves pretty evenly upon all the cell walls. Finally he found that the presentation times where there is such a slight degree of excitation increase in length in the same proportion as the traveling times of a starch grain. Furthermore, about this time Haberlandt had succeeded in giving a wider scope to the statolithic theory. He had come to regard the change of position of the starch grains no longer as a positively necessary condition for the production of a perception, but had come to the conclusion that under certain circumstances, even a one-sided pressure of the starch grains might produce a stimulus. When, then, the starch is evenly distributed over all the cell walls, as in Jost's experiments, "Then in consequence of the effect of the centrifugal force only those grains of starch are capable of exerting a pressure upon the plasma skin which are located upon the external cell walls, *i.e.*, those which are turned toward the periphery of the plane of rotation." Consequently the curve of excitation follows this direction.

Furthermore, if we change an organ from the vertical position in which position the starch grains are located upon the

lower transverse walls of the cells to the horizontal position, then it will immediately happen that there will be a pressure upon the formerly vertical but now horizontal cell walls by exactly those grains which press laterally upon them.

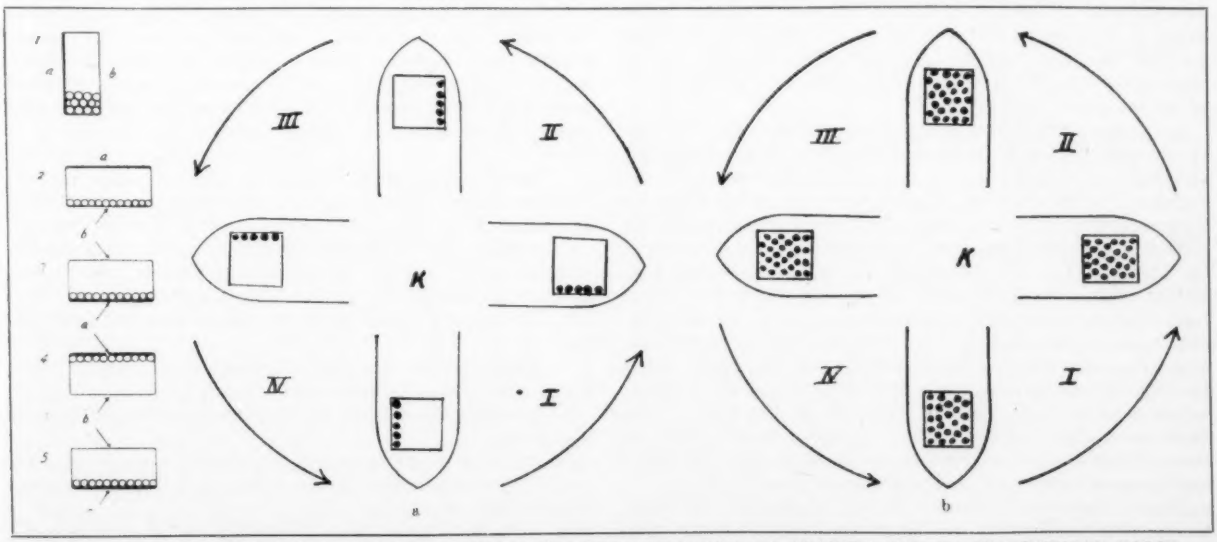
However, when Fitting suggests that the power of the starch grains to change their location is of no consequence so far as the statolithic theory is concerned because of the fact that it is admitted that a mere alteration of the direction of pressure is capable of producing a perception of the stimulus, he goes decidedly too far. An absolute condition for the production of the perception is a certain amount of deformation of the plasma, and such a deformation can naturally be far more readily produced by movable than by immovable particles of starch, and this, too, even when there is no change of position but merely an alteration of the direction of pressure.

As Fitting has shown experimentally the geotropic excitation in the various positions of inclination, alters with the sine of the angle of deviation from the vertical. Consequently the horizontal position is the optimum position for the geotrophic stimulus—and the horizontal position must likewise be the optimum position according to the statolithic theory, by reason of the fact that in the horizontally laid organs all the grains of starch lie next to the lower longitudinal walls. In an oblique position the magnitude of the portion of the wall covered for the time being with starch grains, depends likewise upon the sine of the angle of inclination. This holds good, of course, only in case of a complete change of position of the starch grains.

Buder has also suggested a new way for putting the statolithic theory to the test. He endeavored to create such conditions that the correctness of the theory might be proved not by the lack of geotropic twisting—as in the case of the depredation of starch—but on the contrary *by the very fact of the production of geotropic curves.* For this purpose he laid the roots of the cress plant in a horizontal position for 12 minutes, the time required to distribute the starch grains in an even layer over the now horizontal longitudinal cell walls. The roots were then rotated through 180°, so that the starch-covered walls were uppermost instead of underneath. In this position the roots were again allowed to remain for 12 minutes, during which period of time the starch grains sank to the opposite walls. Such roots have, therefore, starch grains assembled on one side but no impulse to twist since they have been stimulated upon exactly opposite sides for an equal length of time. In this instance the two stimuli balance or "compensate" each other. But it is possible to expose such plants in such a manner that first the longitudinal wall covered with starch grains is at the bottom and then the starchless longitudinal wall, an arrangement which is at once obvious in the diagram in Fig. 1.

If the statolithic theory is correct then curving must occur in the direction of the position in which the starch grains press upon the longitudinal cell wall. Otherwise, there would be no geotropic curves since from a purely physical standpoint both sides have been exposed to the same stimulus for an equal length of time. It was necessary, naturally to make the separate exposures so brief that while they lasted it was impossible for the starch grains to change their positions afresh. Buder obtained positive results from this experiment, since the roots curved in the direction indicated above thus according in their behavior with the requirements of the theory. The correctness of this theory was combated by Zielinski (1911), but a comparison of the work of the two men is convincing as to the correctness of Buder's views.

Buder's experiment was cleverly modified in 1914 by E. Richter, who observed that in the horizontally placed lentil roots the change of place of the starch grains began as a rule before the end of a presentation period and that, therefore, such roots do not curve after the change of position is accomplished. Roots previously thus treated were then slowly rotated about a horizontal axis in such a manner that the walls covered with starch grains were oriented in a perpendicular direction to the plane of location (Fig. 2a). When this was done the starch grains exerted a constant pressure upon the walls where they were accumulated, provided such walls, of course, were situated underneath during the rotation. It was found that here, too, 48 per cent of the 400 hard roots thus treated displayed the geotropic curve. But it is also possible to rotate the roots in such a manner that the starch-covered walls are parallel to the plane of rotation as in Fig. 2b. In this case the starch grains were generally unable to exert any pressure upon the plasma skin next which they lay and only 20 per cent of roots thus rotated formed the geotropic curve. That any such curving occurred is explained by Richter by saying that the roots in question were already stimulated during the horizontal exposure for a somewhat longer time than the presentation period. The results of these two experiments find a simple explanation in the statolithic theory whereas if that be rejected they become entirely



FIGS. 1 AND 2. DISTRIBUTION OF STARCH GRAINS UNDER THE INFLUENCE OF GRAVITY AND OF CENTRIFUGAL FORCE

Fig. 1 shows a cell of the root of the *Lepidium sativum; a, b,* opposite walls of cell. *1,* Position at start; *2,* distribution of grains after lying in horizontal position 12 minutes; *3,* same after being turned 180° and lying at rest 12 minutes; *4* and *5,* position of grains after stimulus every 10 seconds. Fig. 2 shows a cell of the root of the *Linum usitatissimus* according to Richter's experiments; *k,* axis of rotation perpendicular to plane of picture.

incomprehensible. G. and F. Weber raised objections to the statolithic theory in an article published in 1917. In their view the effect of gravity upon the viscosity of the plasma can be perceived. It is clearly true that the velocity with which the starch grains fall depends upon the degree of viscosity of the plasma. Heilbronn has devised a method by which the sinking of the starch grains can be directly observed and their velocity precisely determined. Delicate lamellae are cut from sprouting embryos; these are thin enough to be observed under the microscope but thick enough to contain portions of the starch sheath entirely intact. . . . Thus observed the starch grains are seen not to begin their descent until from ¼ to ½ hour has elapsed, since the plasma reacts to the shock of the wound by becoming perfectly rigid. Using this method G. and F. Weber found that the velocity of the fall was greater when the lamellae received a previous geotropic stimulus by being placed in a horizontal position, or, when there was a stimulation on all sides by a uniform rotation about a horizontal axis. From this and other experiments they came to the conclusion that since the alteration of the viscosity begins before the starch grains have made their change of position, the latter is without significance. We shall not here go further into their experiments since Clara Zollikoffer proved in the exhaustive experiments whose results were published by her in 1918, that the individual differences in the velocity of the fall in the separate cells are so great that it is impossible to make any exact comparison between the behavior of stimulated and of unstimulated cells.

CONCLUSIONS

In conclusion we may mention a still newer experimental message which can be employed for testing the statolithic theory, namely, the Piccard rotation experiment. Darwin first proved that only the extreme point of the root is sensitive to the stimulus of gravity. Similarly, Rotherts has shown that the points of the cotyledon sheaths of grasses are much more highly sensitive to the geotrophic stimulus than the lower portions of these organs. But Nemee found large quantities of movable starch grains in both the root tips and the sheath tips. . . . Piccard conceived the idea of stimulating the base and the tip of the root at the same time in opposite directions by means of centrifugation. This can be done when a root is so attached to an axle rotating rapidly in a horizontal plane, that its tip and the rest of it are found upon opposite sides of the axis of rotation. For a geotrophic curve to be accomplished in such a case, it is necessary for the whole organ to be oriented obliquely to the rotating axis. For this purpose I designed an improved form of the Piccard rotation apparatus. The object of experiment was a cotyledon sheath of an oat plant (coleoptile).

By means of this method Haberlandt showed that the root tip is indeed predominantly sensitive, but by no means exclusively so. If, for example, in the root of a bean plant the extreme 1.5-2 mm. of the tip rise above the axis, there follows a curving of the root away from the axis, *i.e.*, in the direction of the centrifugal force acting upon the tip, in spite of the fact that the zone of growth in which the curvation is mainly accomplished, lies upon the opposite side and is, therefore, excited in the opposite direction. If, on the contrary, only 1 mm. of the tip rises there follows a curving toward the axis, *i.e.*, in the direction of the base of the root. This proves that the latter also possesses a certain degree of sensitiveness which is much less, however, than that of the root. These facts are readily understood when we recall that the base of the root is at a much greater distance from the axis of rotation and is accordingly subject to a much greater degree of centrifugal force. Immediately behind the cap of the root containing the movable starch grain lies the vegetative point of the root, the transverse meristem which forms the cell material for the construction of the root. Since this zone is always found upon the side which decides the direction of the curve, Jost has been led to believe that the seat of the sensitiveness may lie in this meristem. . . . My own experiments, however, indicate that this is quite erroneous. Numerous experiments with various grass seedlings I found that there is indubitably a much greater geotropic sensibility of the point than of the base. In the oat plant, for example, the last 3 mm. of the tip decided the direction of the curve although the whole coleoptiles being studied were from 20 to 30 mm. long, so that the basic portion was subject to a considerably greater degree of centrifugal force.

SUMMARY

Summing up the whole matter the countless experiments made during recent years with respect to the geotropic behavior of the plants can be best explained, in my view, by the statolithic theory, and we are entirely justified in confidently accepting it at any rate so long as nothing better is offered in its place.

THE VISCOSITY VALUES OF PROTOPLASM

IN *The Botanical Gazette* for November, 1920, Dr. William Seifriz of Johns Hopkins University presents the results of studies made on the Viscosity Values of Protoplasm as determined by Microdissection.

In the author's work the method used has been that of microdissection. The instrument employed in this method is a modification of the Barber pipette holder. It consists essentially of two needle holders, each capable of three movements. The holders are fastened to the microscopic stage, and the two needles held in them project into a glass moist chamber in which the material to be worked upon is suspended in a hanging drop of water on the under side of a cover slip which forms the roof of the chamber. The needles are of glass and possess exceedingly fine but rigid tips.

The author's studies are based upon the examination of a considerable variety of material. Consequently, his conclusions may be regarded as rather generally applicable.

The results are summarized as follows:

1. Protoplasm is a polyphase emulsoid system.
2. Physical structure and not viscosity determines the sol or gel state of an emulsion. Consequently, while protoplasm undoubtedly exists sometimes as a sol and sometimes as a gel, yet sol and gel as descriptive terms of the physical state of protoplasm must be used with great caution when viscosity is the only criterion.
3. The viscosity of protoplasm ranges from a degree slightly more than that of water to the firmness of a fairly rigid gel.
4. While a certain degree of viscosity may characterize the protoplasm as a whole, the latter is always more or less divided into regions, whether larger general protoplasmic regions such as ectoplasm and endoplasm, or smaller localized centers of protoplasmic activity such as nucleus and chromatophores, which differ in viscosity from the protoplasm as a whole.
5. Some protoplasmic regions do not noticeably vary in their consistency, but the viscosity of a protoplast as a whole generally varies considerably within a rather wide range.
6. Some of the factors influencing changes in protoplasmic consistency are periodic changes in physiological activity, development, reproduction, mitosis, injury and death.
7. Streaming protoplasm is less viscous than quiescent protoplasm.
8. Young, active protoplasm increases in viscosity as it matures and becomes less active.
9. During mitosis there are very marked regional changes in viscosity.
10. Physical disturbance usually causes a pronounced increase in viscosity, although the rate of increase varies greatly in different individuals.
11. At death protoplasm frequently becomes temporarily very dilute, probably the result of excessive imbibition. Ultimately the degenerate protoplasm coagulates into a solid granular mass, if rapid dissolution has not preceded coagulation.

Snow as a Fertilizer

The Influence of Snow Upon the Development of Spring Vegetation

By M. Peyriguey Jacques

The French peasants have a pithy proverb to the effect that a snowfall in February is worth a pile of manure. This empirical bit of wisdom has recently been pronounced accurate by an agricultural meteorologist at Montpellier, M. Peyriguey Jacques, who has made a careful study of the matter. We give below a brief account of his observations for which we are indebted to La Nature (Paris), for April 17, 1920.—THE EDITOR.

AT Mont-Aigoual in the northern Cevennes (Gard), the ground was covered with snow during the period of 187 days of the meteorological year, 1916, 172 days of which were consecutive; the snow thus provided the ground and the vegetation throughout the winter and the spring with a thermic screen protecting them against frost.

Furthermore, the snow thawed slowly enough to enable the ground and the plants upon it to profit by the addition of nitric acid and of ammoniacal nitrogen thus provided. This provision of nitrogenous matter together wtih the action of the first rays of the sun thus gave rise to an immediate sprouting and a *very rapid* development of vegetation, whose effects are entirely comparable to those obtained in agriculture by the supplying of *nitrates* in the spring. I observed in May particularly the *budding and the complete leafing of beeches during a period of five days.*

a. *Thermic Effects.*—The temperatures of the snow and of the air were obtained by means of dry thermometers; they were recorded at a depth of 0.10 m. and of 0.20 m. in the snow and at a height of 0.20 m. above the surface of the snow; these observations were made from February to May, inclusively.

The following table shows the average monthly temperatures in ten-day periods of the snow and of the air, from the first of February to the first of May. We have omitted the May temperatures from the table, by reason of the thawing mentioned above, the temperature of the snow remained constantly at the freezing point (zero degrees cent.):

Periods	February	March	April
	At 0.20 m.	above the	ground
First decade	— 4.6	— 5.0	5.0
Second decade	— 1.3	1.4	— 9.4
Third decade	— 2.8	1.3	7.0
Daily average	— 2.9	— 0.8	3.9
	At a depth of 0.10 m. in the snow		
First decade	— 2.2	— 4.1	0.0
Second decade	— 1.1	— 1.2	— 0.5
Third decade	— 2.3	— 0.6	— 0.1
Daily average	— 1.8	— 2.0	— 0.2
	At a depth of 0.20 m. in the snow		
First decade	— 2.2	— 4.0	0.0
Second decade	— 1.3	— 1.2	— 0.5
Third decade	— 2.1	— 0.4	— 0.1
Daily average	— 1.8	— 1.8	— 0.2

It results from this that the variation of the average temperature of this thermic screen is nil during the months of February and of March at a depth of 0.20 m. in the snow; at a depth of 0.10 m. in the snow this variation is 0.2 degrees cent.; and at 0.20 m. above the surface of the snow it is 2.1 degrees cent. During the first and third decades of April the variation is nil in the snow, being almost constant during the second decade; the temperature of the air is very variable throughout this whole period.

The accompanying diagram shows that the variations of temperature in the air are much more important than those in the snow, and that the amplitude of these temperatures is as follows:

In the snow	Above the snow
Feb., 5.1 deg. cent.	Feb., 11.5 deg. cent.
March, 7.4	March, 16.4
April, 0.3	April, 21.8

The figures of the tables given above can be compared at a glance, and immediately demonstrate the efficacy of the snow screen as a protection against frost.

b. *Calculation of the Quantities of Nitric and of Ammoniacal Nitrogen Yielded by the Melting of the Snow or by the Rain.*—Snow is always richer in nitric acid than is rain, whereas the proportion of ammonia in rain water is always greater than that of nitric acid. Snow is likewise richer than rain in ammonia.

At the observatory of Montsouris the average amount of nitric acid from 1880 to 1894 yielded by rain water or by the

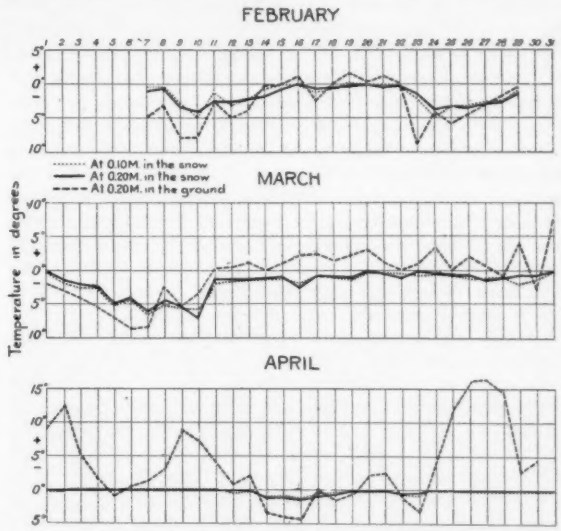


FIG. 1. DIAGRAM INDICATING VARIATIONS OF TEMPERATURE IN THE AIR AND IN THE SNOW AT DIFFERENT DEPTHS

melting of snow was 400 mg. of acid per square meter per year, or 4 kg. per hectare. Likewise at Montsouris M. Albert Levy found that the quantity of ammoniacal nitrogen deposited by rain or snow upon the park, for an average period of 20 years (1876-1895), was 1.086 gr. per year per square meter, or 10.860 kg. per hectare of ammoniacal nitrogen.

But since my own studies covered only a single period of snow I took the figures of the Montsouris observatory, which are almost identical with those obtained by me, and thus obtained, as the total deposit of nitrogenous compounds furnished to the ground and to vegetation by the melting of the snow and by the rain, and with an average precipitation of water of 551 mm. of water per year, 0.400 gr. as the average quantity of nitric nitrogen per square meter of the surface and 1.086 gr. as the average quantity of ammoniacal nitrogen per square meter of the surface. As these figures show, the ground at Montsouris was thus enriched by a total amount of nitrogen equal to 14.860 kg. per year per hectare.

For Mont-Aigoual we find for a period of six months (December to May, inclusive), and for a depth of rain water or of melted snow equaling 1621.7 mm., that the ground is enriched by 43, 736 kg. per hectare of nitrogenous compounds.

VARIOUS PHASES IN THE MANUFACTURE OF BILLIARD BALLS

Making Billiard Balls from Ivory

The High Degree of Skill Required, and Some of the Valuable By-Products

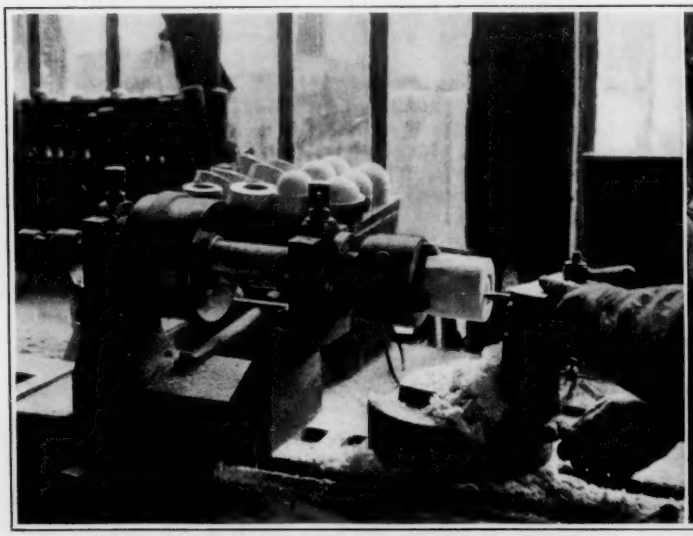
By T. A. Marchmay

ONE of the most beautiful of all natural materials both in color and in texture is the ivory of which the tusks of the elephants and other great pachyderms are formed. This has been universally recognized for centuries, not only among the Greeks and other civilized peoples of antiquity but among savage tribes. One of the most interesting exhibits at the American Museum of Natural History in this city, for example, is the remarkable collection of carved ivory figures brought by Mr. Lang from the heart of the African jungle, where they formed the treasures of a king, while to complete the picture, the great Phidias himself employed ivory as one of the most fitting materials obtainable to enshrine those visions of beauty with which he endowed mankind.

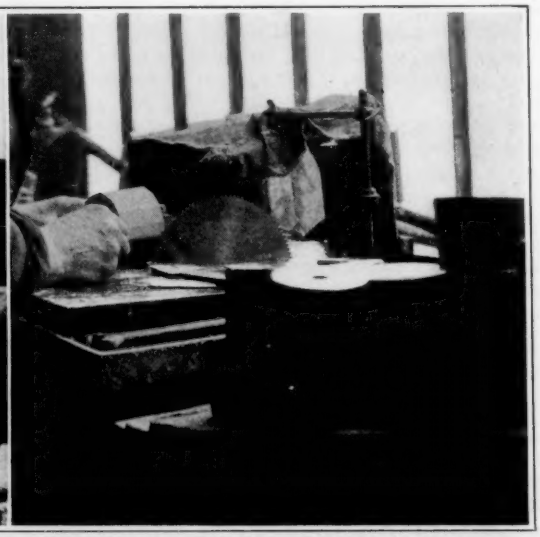
But ivory has certain physical properties besides its color and texture which make it eminently fitted for the construction of certain objects other than works of art. Chief among these properties is its elasticity and it is this which makes it *par excellence* an appropriate substance for the manufacture of billiard balls, since these are subject to constant shock and must instantly rebound to properly fulfil their function. Another quality of ivory, making it suitable for this purpose is the comparative ease with which it is worked. A billiard ball, for example, in order to be "true" must be absolutely spherical, since the slightest deviation at any point from perfection of curve would render it liable to deviate from the course the sure eye and deft hand of the player cause it to follow.

A third quality of ivory which renders it valuable for this purpose is the readiness with which it acquires a high polish, since this, of course, tends to diminish friction, which might interfere with the velocity of the ball, or even with its pursuance of the path the player intends that it shall take.

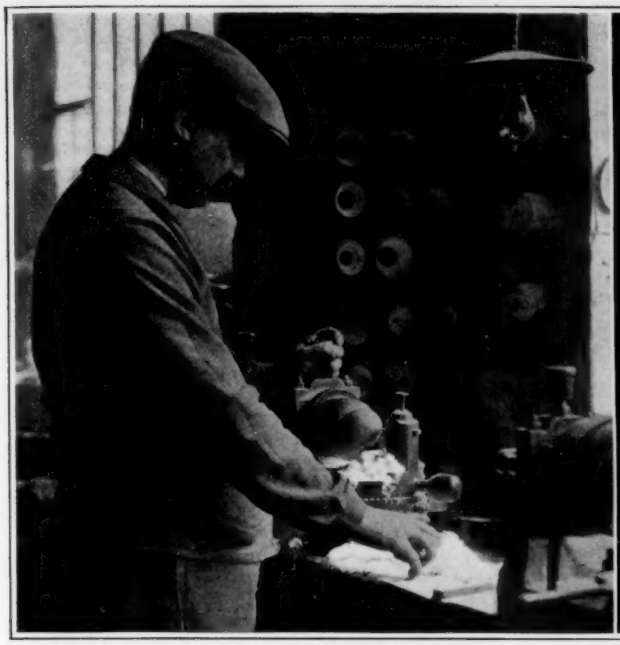
It is evident from the foregoing remarks that the manufacture of these delicate implements of play is a highly specialized affair and it is the main object of this article to describe the processes involved. Ivory is merely a form of dentine, *i.e.*, the hard and bone-like substance of which the teeth of most mammals are composed. But it is exceptionally tough, elastic and uniform in texture because of the fineness and regularity of the minute channels, known as dentinal tubules, which radiate from the pulp cavity in the center of the tooth to the latter's outer surface. The most valuable ivory is that obtained from elephant's tusks, in which these tubules bend sharply at regular



THE IVORY BLOCK IN THE LATHE, THE BALL BEING TURNED IN THE BLOCK



TRIMMING AND SQUARING THE SURFACE OF THE IVORY BLOCK



TAKING THE FINISHING CUT

POLISHING THE SPHERE

and frequent intervals, so as to produce a characteristic pattern in the material. Female tusks are more valuable because they grow more slowly and are harder, tougher, and more elastic, as a result, with narrower annual rings of growth.

The best ivory comes from the African elephant, whose tusks are also larger than those of the Indian elephant, sometimes attaining a length of 9 feet and a weight of 160 pounds.

When first cut African ivory is semi-transparent and rather dark, becoming more opaque and lighter in color as it dries. In its natural state it is coated with a sort of cement, and when observed in cross section it exhibits not only the fine angular radiating lines described above, but also the "rings" which are concentric with the axis of the tooth, being arranged about a central grayish spot which represents the former pulp, now calcified. Ivory is richer in organic matter than most dentine, containing 40 per cent or more. The arrangement of the rings is due to the regular placing of minute cavities known as interglobular spaces.

At the present time ivory is extremely costly, the price of a tusk being from 4,000 to 5,000 francs. Since it is likewise one of the frailest and most easily injured materials which comes under the hand of the turner or the carver, it is evident that the workmen entrusted with it must possess both delicacy of touch and expert skill. It is said that there are only about 50 men in Paris engaged in the industry of making billiard balls in that city. In spite of the great care exercised by these skilled artisans, many accidents occur, especially since the finer and handsomer the ivory the greater the precaution necessary to protect it from heat, sunlight, currents of air, and other influences which may cause it to crack. Sometimes indeed, when the conditions appear to be perfect, a sudden explosive sound, like a pistol shot, is heard, and the operator sees the object under his hand split into two parts. Usually the crack, however, is very narrow, merely the thickness of a knife blade. While such cracks or splits gradually come together again, the object bears an ineffaceable scar, so that the artisan's work is lost. Other unpleasant surprises may be in store for the worker in this fragile material. Sometimes when the work is already quite far advanced a number of small yellow spots make their appearance; these indicate the presence of areas similar to the knots found in wood; the slang name for them in the trade is "beans." When these appear the material must likewise be cast aside. Again the tusk has sometimes been injured during the capture of the animal. Occasionally a bullet is found to have traversed the hollow of the tusk and buried itself in the heart of the latter where the most beautiful ivory is found. Here it produces a sort of caries which appears from point to point, sometimes extending around the heart throughout the whole length of the tusk.

MAKING BILLIARD BALLS

All these things serve to make the price of billiard balls, which as we have said must be perfect as to form, toughness, and elasticity, comparatively expensive. As our pictures show, a special technique is employed in their manufacture. The balls are not simply *turned* as one might suppose. The tusk in hand is first sawed into sections of the proper size, after which the sides are trimmed off, the small pieces of ivory produced by the trimming of the block being employed to make handles for handsome knives. When the blocks are

POLISHING IVORY BRACELETS

ready a foreman takes charge of them and draws upon the surface of the section by means of a metal template, a pencil mark which serves to indicate to the workman the line to follow in his work. The block is placed in the chuck of a lathe and by means of a curved tool of peculiar shape, called the *outil à ouvrir*, the ivory worker transforms one part of the block of ivory into a half sphere. Little by little the tool penetrates the bit of ivory which is rotated at high speed.

The workman then passes the block of ivory to one of his companions who turns it about and begins to accomplish the same work on the other side. In this way when the second man's work is finished a round ball of ivory, capable of rotating freely, has been cut from the original block. In order to extract this ball from its socket it is only necessary to saw the block circularly around the ball. The most difficult part of the manufacture has now been accomplished but before the final polish can be put upon the finshed ball, it must

A VALUABLE LOT OF ELEPHANT TUSKS TO BE MADE INTO IVORY BILLIARD BALLS

remain for six months in a drying apparatus. When properly dried it is placed in a socket in the lathe and polished by pressing against it a piece of cloth covered with a mixture of Spanish white and suet.

French balls are required to have a diameter of 25 to 68 mm. and Spanish balls of 68 to 74 mm., while those sent to the Philippines have diameters running as high as 80 mm. According to a French writer, Jacques Boyer, professional billiard players, insist upon having balls made from the ivory of the Indian elephant. They likewise demand balls which are perfectly centered and entirely free from the slightest flaw. At the present time a set of such balls costs from 800 to 1,000 francs in Paris.

Sometimes the blocks of ivory into which the tusks have been sawn, or even the block in which the balls have already been formed, are placed in the hands of a *tubeur* who sets them upon a sort of lathe and by means of a brass tube, with a toothed edge, saws them into rings which are later made into bracelets. These heavy and rather clumsy ivory bracelets are then sent to be carved in decorative designs, after which they are shipped to India to adorn the arms of native rajahs. Thus a bit of ivory may take quite a little journey in the world, being captured in the Congo, shipped to dealers in Belgium, from them to maufacturers in Paris, and from these to potentates of the Far East.

SOAP ANALYSES

THE fourth of a series of articles on guides to analyses which have been appearing in the *Chemical Bulletin* published by the Chicago section of the American Chemical Society, is devoted to the interpretation of soap analyses. The components of soap can be grouped under these headings: (1) The anhydrous soap which should be the principal ingredient and is the basis upon which soap should be bought or sold and evaluated; (2) the alkaline fillers which determine the suitability of soap for specific uses; thus a toilet soap should be practically free from uncombined alkali and for some industrial applications only the smallest quantity of free alkali can be tolerated. There are places, however, where a strongly alkaline soap is to be preferred; (3) the inert fillers indicate whether or not soap has been deliberately adulterated; and (4) special ingredients must me identified where special claims have been made for the soap. For example, the presence of a rather fine abrasive material would be an adulterant in laundry soap but one of the most valuable components is a scouring soap. The chemist must, therefore, not only be able to identify and possibly measure the quantity of a wide range of special components but must be thoroughly informed as to the uses of the soap before he can properly interpret its analyses; (5) moisture is usually determined in order to check up the complete analyses but is not of special importance; (6) the nature of the stock which has been used in the manufacture of the soap presents a problem which is often more difficult than the analyses itself. Rosin can be determined with a reasonable degree of accuracy, but its presence interferes in estimating the composition of the fats used especially if there be more than one which is usually the case. Added to all this are the aging problems for soap due to its nature which is subject to change due to oxidation and to reactions which, for example, cause free caustic to become converted to carbonate due to the absorption of carbon dioxide. Silicate of soda upon the absorption of carbon dioxide will decompose producing carbonate of soda and silicic acid which will, on analysis appear as an insoluble filler. Aging may also give rise to apparent high free acidity due to the oxidation of acids and this is usually accompanied by discoloration. This is particularly prevalent in chip soap where there is a maximum surface exposed.

It is apparent from the article that the analyses of soap and the proper interpretation of the data thus obtained is far from being a simple undertaking.

CAUSES OF SKIN SORES AND BOILS AMONG METAL WORKERS

THE research laboratory of E. F. Houghton and Company has brought together in the form of a pamphlet the results of investigation conducted early in the war on the subject indicated above which is the title of the publication. For many years there has existed a most serious problem in the metal cutting industries where there have been epidemics of sores and boils among the operatives. This was most frequently attributed to cutting oil although in some instances the liquid was actually a diluted soap. The trouble became serious in munition plants, hence the independent investigation of the subject which is now available in printed form. The company which financed the investigation and the publication of the report offers to send copies to those who are in a position to make good use of the information.

Friction and Lubrication*

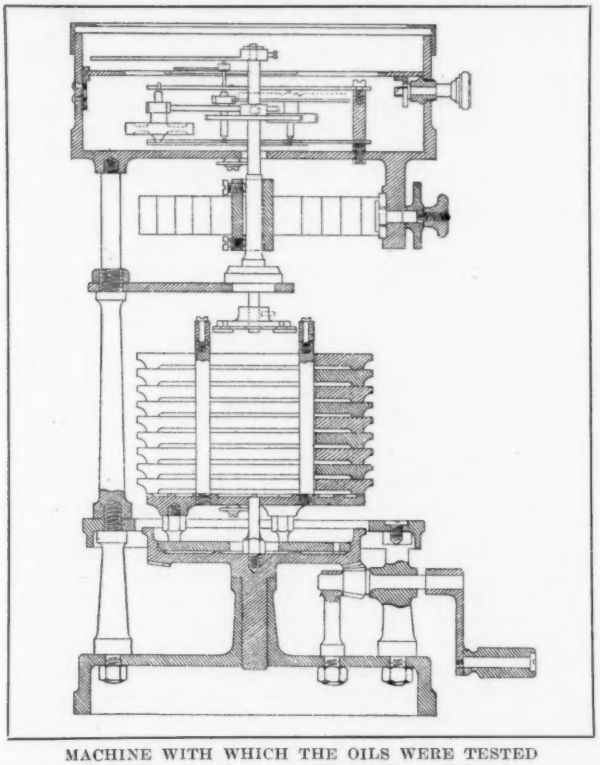
Is There a Chemical Combination Between the Molecules of the Metal and the Lubricant?

By R. Mountford Deeley

THOSE who have had to deal with the lubrication of machinery have found that the value of a liquid as a lubricant does not depend wholly upon its viscosity, for many moderately thick liquids will not prevent opposing metals from wearing and heating, while others will. We have thus come to regard oiliness as an important property of lubricants.

Under many conditions of work the opposing surfaces of machines are entirely separated by the lubricant, and our knowledge, so far as it goes, tends to show that the friction is almost, and often wholly, due to the viscosity of the lubricant. However, there are conditions of work during which such a thick oil film does not form and the oily surfaces touch each other.

The friction experiments now to be described were made under conditions which ensured that the surfaces should be



MACHINE WITH WHICH THE OILS WERE TESTED

in actual contact, and any differences in the frictional coefficients shown by the oils tested must have resulted from the contact of the oily metals, and not from the free molecules of the liquid itself.

The experiments were made with a hand-driven machine easily manipulated. Three pegs, each 5/32 inch in diameter, rested upon the flat surface of a disc of metal which could be slowly rotated. These pegs were secured concentrically to an upper disc which could be weighted as desired and which actuated a spindle to which a spiral spring and recording finger were attached. When the lower disc was rotated the pegs were carried with it by friction until the surfaces slipped owing to the stress on the spring, and the finger then gave the value of the frictional stress reached. To damp the oscillations of the finger, the spindle to which the finger and spring were attached was geared to a small train of wheels, the freely revolving end wheel of the series having a weighted rim to increase its inertia. When measuring the static coefficient a pawl and ratchet were thrown into gear with the indicating finger to prevent it from moving toward zero if an oil film should form and the surfaces part. By very slowly moving the driving handle the finger was quickly brought to the position giving the static coefficient. The movable disc upon which the pegs rested lay in a circular dish, which could be filled with oil and slowly rotated.[1]

To ensure clean surfaces, or surfaces as clean as possible, the metals were ground in water with flour of carborundum. They were then polished with fine wet emery cloth, dried with clean blotting paper, and finally heated to get rid of all traces of moisture. The temperatures of the surfaces during the experiments varied from 16° to 18° cent.

Such clean surfaces are very sensitive to any contaminating agency. In one instance such a surface gave a momentary static friction coefficient of about 0.160. This surface was then breathed upon for about two seconds, and a further test gave a coefficient of 0.452, and it had to be repolished. Although the tests so far made showed that animal and vegetable oils largely displaced mineral oils from surfaces, mineral oils would not displace animal and vegetable lubricants.

Each friction value given in the tables to follow is the mean of five determinations at loads per square inch of 52 pounds, 43.3 pounds, 36.6 pounds, 26 pounds, and 17.3 pounds respectively.

The first experiments were made with mild steel upon cast iron and then with mild steel upon gun-metal.

Dry Surfaces.—Surfaces may be contaminated with oil and yet not be wet. The coefficient of friction—static—varies very much with the condition of polish of the surfaces, as well as with the nature of the contamination.

When the surfaces are properly ground and polished and no lubricant is used, the static coefficient becomes greater and greater as the surfaces continue to rub against each other. The initial static friction of a clean surface of mild steel resting upon cast iron was, in one instance, 0.154, and rose in the course of about ten minutes to 0.417, and was still rising when the experiment was stopped. A series of experiments was quickly made with surfaces of mild steel and cast iron, all quite clean. The results are shown in Table I. The surfaces during each experiment were worked upon each other as little as possible, so as to alter the condition of their surfaces as little as possible.

Table I—Mild Steel Upon Cast Iron

Load per sq. in. lb.	Static coefficient.	Kinetic coefficient.
52.0	0.167	0.175
43.4	0.173	0.188
34.6	0.184	0.197
26.6	0.204	0.204
17.3	0.213	0.223
8.6	0.230	0.229

*Reprinted from *The Engineer* (London), Jan. 21, 1921, p. 78. Preliminary report communicated to the Lubricants and Lubrication Inquiry Committee of the Department of Scientific and Industrial Research on December 5, 1918, and not hitherto published.

[1]Further details of Mr. Deeley's machine will be found in the Committee's recently issued final report, from which report our engraving is reproduced.

Lubricated Surfaces.—In the case of lubricated surfaces the procedure was as follows:

Clean surfaces were wetted with the lubricant, which was then wiped off, and the surfaces worked in contact for a time. When contact had taken place between the pegs and the disc below a dark streak was left; this was removed with clean dry blotting paper. The working of the surfaces together tended to smooth them, and it was found that the more this was done the more nearly the static and kinetic frictions approached each other. As the friction value thus obtained varied with the extent to which the surfaces were cleaned, no real value attaches to these results; but the test was considered useful, as it brought the rubbing surfaces into good condition. In Table II. some results obtained in this way are given.

Table II.—Rape Oil with Mild Steel on Cast Iron

Lbs.	
52.0	0.205
43.3	0.200
34.6	0.203
26.0	0.208
17.3	0.218
8.6	0.229

The static and kinetic coefficients were practically the same.

Surfaces prepared as above were then flooded with oil. In this condition, even when the speeds of rubbing were as low as 2 feet or 3 feet per minute, they separated and a thick oil film was generally formed. Under these conditions the coefficient of friction was much lower than when the surfaces were in contact. Sometimes, in the case of the kinetic coefficient, there was reason to suppose that the friction was partially due to the contact of the surfaces as well. Table III illustrates such a case.

Table III.—Mild Steel on Gun-Metal

Load, pounds...	52.0	43.3	34.6	26.0	17.3	8.6
F.F.F. cylinder..	0.052	0.058	0.067	0.081	0.100	0.172
Sperm	0.061	0.053	0.045	0.036	0.029	0.020

Here the kinetic coefficient of friction of the mineral oil decreases with increase of load; but in the case of sperm oil the coefficient increases with the increase of load. At the higher load the sperm oil film was being pressed out and every now and then the indicating finger gave a jump forward.

Table IV. shows the static coefficient and efficiencies of a number of oils tested between mild steel and cast iron and mild steel and gun-metal. The efficiency is—

100 — (static coefficient × 100) = efficiency.

Table IV

Lubricant	Mild steel on cast iron		Mild steel on gun metal	
	Static coefficient	Efficiency	Static coefficient	Efficiency
Clock oil	0.271	72.9	0.275	72.5
Bayonne	0.213	78.7	0.234	76.6
Typewriter	0.211	78.9	0.294	70.6
Victory red	0.196	80.5	0.246	75.4
F.F.F. cylinder	0.193	80.7	0.236	76.4
Manchester spindle	0.183	81.7	0.262	73.8
Castor	0.183	84.7	0.169	83.1
Sperm	0.127	87.3	0.189	81.1
Trotter	0.123	87.7	0.152	84.8
Olive	0.119	88.1	0.196	80.4
Rape	0.119	88.1	0.136	86.4

There is a marked difference between the friction of the various oils when the mild steel is opposed by cast iron and gun-metal respectively. Rape and olive give the best results and mineral oils the worst, castor coming between the mineral lubricants and the rest. Rape and olive are of equal value between mild steel and cast iron, but rape is the better between mild steel and gun-metal.

The value of such a test as an indication of the lubricating value of an oil depends entirely upon the mode of preparing the surfaces; for very irregular results are obtained if care be not taken in this respect. With greater experience better methods may be devised. Indeed, more recent experiments have shown that even more reliable results may be arrived at. It was found that unless the water be all driven off the surfaces by heating them well, contradictory results were obtained. However, the figures given in Table IV. are probably of the proper order of magnitude in each case.

Theoretical.—The coefficients of friction given in Table IV. make it clear that the static friction varies not only with the lubricant, but also with the metals in contact, and that oiliness is rather an effect produced by the lubricant upon the surfaces than a property of the lubricant as a liquid.

When the skin of a metallic surface has been removed by a file the file cuts the metal more easily, but if such a clean surface of metal be slightly oiled, or even if the hand be rubbed over it, the file will not cut anything like so easily. Thin films of matter of this kind cannot be wiped off. It is necessary to grind the surface in water, when the water readily wets the surface and it is easily abraded.

Oily liquids would appear to be those the molecules of which readily and firmly enter into combination with the molecules of the metallic surface. The combination appears to be not merely with the molecules at the surface, for it is necessary to remove a comparatively thick crust before clean metal is reached. Roberts Austin[2] remarks: "The continuation of these experiments has led to the recognition of the remarkable fact that diffusion of metals can be readily measured, not only in the molten state, but in solid metals. It is certainly remarkable that gold, placed on the bottom of a cylinder of lead 3 inches high and heated to only 200° C. or 400° F., which is far below its melting point, and while it is to all appearances solid will have diffused to the top in notable quantities by the end of three days . . ." It is possible that the molecules of a liquid lubricant, or those of a lubricating grease, penetrate the metal for some considerable distance in a similar way and form a comparatively thick film of a compound which acts as a lubricant.

Dunstan and Thole[3] remark: "It appears, then, that the true lubricant is an unsaturated compound, possessing all the attributes of such a compound, *i.e.*, (1) capacity to absorb iodine, bromine, oxygen, and so on; (2) solubility in strong sulphuric acid; (3) higher C/H ratio than the saturated derivative. Apparently the same facts hold good in relation to fatty lubricants. Rape oil, castor oil, and olive oil contain in their molecules double bonds, and are superior in body and viscosity to such a saturated product as, for example, tallow."

The unsaturated molecules of the lubricant seem to attach themselves to the molecules of the metals they wet, and form skins capable of preventing the "free" molecules of opposing metallic surfaces from adhering. If such be the case it is reasonable to suppose that the friction coefficient between such metallic skins would vary with the metals in contact as well as with the nature of the oil.

NEW STANDARD SAMPLES OF STEEL AND BRONZE

A NEW standard sample of electric steel No. 51, 1.2 per cent carbon, and a new standard sample of cast bronze No. 52 (approximate composition, copper 88 per cent, tin 8 per cent, zinc 2 per cent, lead 1.5 per cent, antimony 0.15 per cent, iron 0.10 per cent and nickel 0.10 per cent) have recently been prepared by the Bureau of Standards and are now ready for distribution with provisional certificates.

[2] Fourth report of the Alloys Research Committee, p. 58.

[3] *Journal* of the Institution of Petroleum Technologists, June, 1918, p. 205.

The Colloidal State of Matter

A Review of Recent Investigations in Colloidal Chemistry

By John J. Birch, Pd.B.

MATTER, as we understand the term, exists in three forms, namely: solids, liquids and gases. Until recent years it was believed that matter existed only in the crystalline state; but after critical investigation the crystalline theory of matter has been found inadequate to explain all its existing states, and consequently matter has been divided into two states: colloidal and crystalloidal. Investigations along three particular lines led to the assumption that it exists not only in the crystalline, but also in some other phase.

In 1827, Brown, the English biologist, studied the biological state of the motion of microscopic animalcules in liquids and found that infinitely small material particles in liquids possessed a similar characteristic motion. This has contributed important complements to the Kinetic Theory of matter and built up the hypothesis of the Brownian Movement. About 1850 English microscopists in their endeavor to increase the magnifying power of the microscope, in order to study the hypotheses of Brown, introduced the method of illumination, known as "dark background illumination."

The last line of investigation was the contribution which Faraday unknowingly made. One of his keen ambitions was to show experimentally the connection between electricity and light. In pursuance of this object, he sought to find the effect exerted on light by very fine particles of metal suspended in liquids. He prepared several solutions of silver and first suggested what is now believed to be the true constitution of these solutions.

A solution, as we understand the term, is the absorption of one body, by or into another, giving the characteristics of homogeneity, non-settling and minute subdivisions of the dissolved substance. They are generally defined as homogeneous mixtures, inasmuch as they never separate mechanically into components and are so completely dispersed that any solid particles cannot be recognized even by optical methods. The word is used for other systems than those containing a solid dissolved in a liquid. Liquids may be dissolved in liquids, as alcohol in water; and the absorption of nitrogen by iron takes place in accordance with the same laws as the solution of solids in liquids, and is just as true a solution. The absorption of liquids by solids and homogeneous mixtures of solids are perfectly familiar. The sapphire is a solution of a small amount of strongly colored substance in a large amount of colorless aluminum oxide. It may therefore be stated that solutions of gases, liquids and solids in liquids are possible, yet there exists no form of crystalloidal solution having the same properties and characteristics as the colloids. At the present time we do not speak of the differences between colloidal and crystalloidal matter; but only separate the colloidal from the crystalloidal states. The chemistry of colloidal therefore is the science of the colloidal state of matter.

COLLOIDS AND CRYSTALLOIDS

Although the nomenclature and scientific researches relative to colloids have been one of the more recent problems of chemistry; yet colloids existed and their peculiar properties were made use of by the ancient peoples. Substances in the colloidal state were employed in the early stages of human culture as adhesives and the Egyptians used such substances as starch and dextrin in dyeing. The Chinese allowed their clay and porcelain to decompose which increased colloidal substances in them and raised their degree of plasticity. The term "colloid," derived from the Greek (kolos) which meant to glue or that which was incapable of crystallizing, was proposed in 1861 by Thomas Graham. He used the name to designate those substances which were incapable of diffusing through porous membranes. Substances such as salt, hydroxides and mineral acids which diffuse readily through membranes were called "crystalloids." Recent investigations have shown that the colloidal condition is possible not only for a limited class of substances, but is in general, possible for many, if not all. One might define colloids then, as the condition of insoluble substances, in so far as ordinary observation and the common methods for separation of heterogeneous phases are concerned, as those forms of matter which exist in a non-crystalline state, remaining suspended in water and which pass unimpeded through filters. An extremely finely divided solid suspended in a liquid is the most common type of such mixtures. The most important substances in the colloidal state are starch, albumin, tannin, dextrin and gelatin.

Colloids were first thought to be difficultly soluble substances in solution. For many years the belief was prevalent among chemists that these liquids represented true solutions of difficultly soluble substances in the form of soluble modifications of the substances. Like ordinary solutions the liquids were found to show a certain osmotic pressure, but unlike ordinary solutions the osmotic pressure was very small in proportion to the quantity of substances present.

Substances	Concentration Per cent	Osmotic Pressure Cm. Mercury
Gum Arabic	1	6.9
Dextrin	1	16.6
As_2S_3	4	1.7
$Fe(OH)_3$	1.1	0.8

There were other chemists who considered the colloidal liquids to represent suspensions of minute solid particles in an extremely small state of subdivision. The correctness of this has been proven conclusively by observations made upon such solutions with the ultra-microscope. The colloidal solutions of gold are seen to contain minutely small particles of gold, the diameter of which ranges between 60 and 6 $\mu\,\mu$. The size of the particle likewise influences the color of the solution. There are still finer subdivisions the diameter of whose particles cannot be measured.

A large number of apparent solutions resembling true solutions even less closely than colloidal solutions, are known as crystalloidal suspensions. Several methods of preparing these have been worked out and applied. Colloidal suspensions of many of the metals also have been prepared by electrical means. If a dilute solution of a metal be electricalized, the metal is not deposited on the cathode; but the arc under the water, tears the metal from the cathode in a very fine state of subdivision and these remain suspended in the water, which in turn becomes discolored. It is then filtered to remove the larger particles. When a drop of this is placed under a powerful microscope, the fine state of subdivision can be seen. The particles in this suspension bear an electric charge which is shown by the fact that they move through the solution under the influence of the current.

ELECTRIFICATION OF COLLOIDS

One of the important discoveries made on colloids was the observation that the suspended particles of a great number of colloids bear an electric charge—thus creating a potential difference between the particles and the liquid in which they are suspended. The liquid holding the colloid in suspension seems to have control over this electrical charge. For example; colloidal platinum in water is negative; while in a mixture of alcohol and water, a positive charge is manifest. All

amphoteric colloids, or those which have acid and basic properties, change the character of their charge, when the liquid in which they are suspended is made to pass from an acid to an alkaline condition and vice versa. Silicic acid in the colloidal state, changes from negative to positive as the solution passes from a basic to an acid reaction. Albumen, which is likewise an amphoteric colloid, shows some change of charge in the colloidal condition, and the charge has been ascribed to the change of basic or acid functions.

The electrification of the colloid may result from what is known as contact or surface electricity. There is always a potential difference between the surface of two different substances. Then in the case of colloids, which are finely divided suspensions, the contact surfaces are enormous as compared with the surfaces involved in ordinary contact. The area of each particle, multiplied by the number of particles, would give a tremendous area. However, very little is known relative to contact electricity; but it has been conjectured that it does not differ from ionization. This fact remains yet to be fully established. Whether certain metals such as gold, platinum and silver owe their charge to contact effects, or to their tendency to ionize is not definitely known. Although the source of the electrification of colloids is as yet only a conjecture, still we can calculate the charge which each particle bears with a high degree of accuracy.

It would seem possible to calculate the charge on colloidal particles, by determining the conductivity of a colloidal solution of a metal prepared by sparking; for in such a solution the amount of foreign electrolyte would orlinarily be very small and any conductivity would necessarily be due to the transference of electricity by the particles themselves. The average charge per particle has been found to be 2,385 x 10^{-10} electric units, or 795 times that of the hydrogen ion. If the particles carry a negative charge, some positive ions must be present as well, for the colloidal solution as a whole remains unchanged. Calculations are made on this assumption, giving results inconsistent with those obtained by the use of Stokes' formula, assuming the mobility of the positive ion to be equal or less than that by the hydrogen ion. This is the same as to say that the positive and negative ions are absorbed by the particles; both being in excess at different distances from the particle, and may serve to explain the movement of the particles. Probably the first method suggested for determining the size of the colloidal particle however, dependent upon the application of Stokes' law for the rate of fall of solid spheres, through a liquid medium. Assuming that a body be falling through air and that the only active force is gravitation; then by Newton's law the distance which the particle falls is expressed by the formula $D = \frac{1}{2} (a\ t)^2$. In the case of the colloidal particles, we have several different conditions. The forces of friction and the Brownian movement in the colloid itself are the added factors. According to Stokes' law, a sphere tends, after a short interval of time, to attain a limiting velocity, (v), such that the forces of friction exerted by the fluid is expressed in the equation $F = 6\ \pi\ nav$, where (n) is the coefficient of viscosity of the fluid and (a) the radius of the particle. For a steady motion, this force must necessarily be equal to the forces of gravity which act on the particle emersed in the fluid. The latter force is given by the equation $F = 4/3\ \pi\ a^3\ (p - p')g$, where (p) and (p') are densities of the material of the particles and of the fluid respectively. Equating these forces, we have:

$$\tfrac{4}{3}\ \pi\ a^3\ (p - p')g = 6\ \pi\ nav. \quad a^2 = \tfrac{9}{2} \times \frac{n\ v}{(p - p')g}$$

Particles which have a radius less than 10^{-5} cm. are overcome by the Brownian movement and settling of the colloidal particles is prevented, thus giving the formula a very narrow application for aqueous solutions. If there is a tendency to settle, the particle must first attain a limiting velocity, (v) corresponding to Stokes' formula: Weight = $mg = 6\ \pi\ nav$, where (mg) is the gravitation pull on the particle in water. An interval of time is required when the particle begins from rest and is accelerated under the forces of gravity. The smaller the particle the less the limiting velocity, and at the same time, the smaller the particle the greater will be the force of the Brownian movement caused by molecular shocks. When the Brownian movement is so large, that is to say, when the molecular shocks in various directions are so pronounced that the particles do not attain a limiting velocity in a downwise direction due to gravity, the particles do not show any disposition to settle.

THE BROWNIAN MOVEMENT

Before the time of Brown many microscopic objects suspended in water had been observed to be in rapid movement; but this phenomena was supposed to be connected with activities of living matter. Brown disproved this by furthering the experiments of Needham and Gleichen on the observation of the movement of the minute spherical pollen particles in a liquid. He examined the aged spore dust of mosses and equiseti in order to prove whether or not the motion was a phase of life. Finding that from these there was a lively motion, he examined inanimate substances as lead, bismuth, arsenic, sulfur, rocks, glass, coal, and gums finding the same movement in each. Brown suggested that the cause of the movement arose neither from currents in the fluid nor depended upon the movement of a fluid attending its evaporation. Guoy attributed this motion to thermal vibration of the molecules in the liquid. Ramsay and Cantoni believed the motion was related to the size of the particles and not to the material of which they were composed.

Ramsay believed that the velocity depended upon the size and density of the particles. It was his belief that the particles in pure water do not touch each other at any time, and that they do not exert an influence one upon another. This brings us to the invention of the ultra-microscope which has since made possible more thorough examination relative to the size and motion of the particles in the Brownian movement. This movement has many suggested causes. The motion is not due to the infusoria, for Brown found that the motion exists with inanimate objects, such as metals, rosin, glass, etc. The motion is not due to internal changes as mechanical vibrations from surrounding objects incident light and heat. Extensive researches on this hypothesis have been made by Wiener, Exner, Guay and Zsigmondy. The influence of gases surrounding the particles also does not cause this motion. Small bubbles of gas contained in a liquid enclosed in spaces in certain minerals, are in constant vibration and when the bubbles are below 0.002 mm. in diameter they are subject to a constant quivering motion. The motion in this case is caused by an incessant interchange between the molecules of vapor in the bubbles and those of the liquid which surrounds them. Evaporation of the liquid would not cause a motion, for when heat rays fall upon a solution they do not cause any pronounced change in the motion. Brown made extensive investigations from this standpoint. Also the influence of gravity, magnetic or electrical forces between the particles cannot explain the motion, for it has been found, almost invariably, that the addition of electrolytes stops the Brownian movement. Surface tension does not seem to be its source. Fuchs has formulated several laws relative to the part played by surface tension in deciding whether small particles will unite to form larger ones or still further subdivide. "If the molecules of the liquid are attracted more strongly by those of the solid, than they are by the molecules of the liquid when the molecules of the solid attract one another the potential energy will be a minimum when each particle of a solid is surrounded by a shell or liquid of a thickness equal to the radius of molecular forces. The two particles will then repel each other if brought closer than twice that distance. If either of the forces solid—solid or liquid—liquid is greater than the force solid—liquid the potential energy will be lessened when the two particles are made to approach as closely as possible. They will then attract each other."

That internal heat energy is the source or cause of the vibration seems to be the best theory. As the temperature rises the velocity increases and the viscosity of the dispersing medium decreases. Viscosity and temperature are dependent on each other for the viscosity of the medium is decreased with a rising temperature.

The Brownian movement exists in gases as well as in liquids. Ehrenhaft was the first to carry out direct measurements on the Brownian movement of particles in gases. He found that there was a much livelier movement in gases than in liquids and that the action of gravity in causing a vertical decent of the particles was also much more apparent in gases than in liquids. In the larger particles, found in the smoke of cigars and the fumes of ammonium chloride he found pronounced Brownian movement, while in the smaller particles obtained by an electric discharge between zinc, platinum or silver electrodes he found the motion very rapid. The measurements on cigar smoke particles gave a mean velocity of 2.5×10^{-3} cm/sec. while on the smaller particles of silver the mean velocity was 4.6×10^{-2} cm/sec. The following tables gives the velocities impressed by molecular shocks and by the force of gravitation respectively on silver particles of various sizes (density 10^{-5}) and shows that when we reach particles having diameters of the order of the wave length of light the two velocities do not differ materially; but in the smaller particles the velocity induced by gravity soon becomes negligible, while the particles increasing above 10^{-5} cm. the motion due to gravity is dominant.

Radius of the particle in cms.	Velocity in cms/sec. due to molecular shocks.	Velocity in cms/sec. due to gravity.
1×10^{-7}	6.3×10^{-3}	12×10^{-5}
5×10^{-7}	2.8×10^{-3}	3×10^{-5}
1×10^{-6}	2.0×10^{-3}	12×10^{-6}
1×10^{-5}	6.3×10^{-4}	12×10^{-4}
1×10^{-4}	2.0×10^{-4}	12×10^{-2}

Brownian Movement Velocities

Material	Diameter $\times 10^5$ cm.	Medium	Temperature	Velocity $\times 10^5$ cm/sec.
Gamboge, Quartz	10.0	H_2O	18°	23.0
Silicic acid, White lead	16.0	"	"	5.0
Sulphur	4.0	"	21°	38.0
Dust part.	2.0	"	—	0
Platinum	0.4	Aceton	18°	3900
Gold	0.06	H_2O	20°	700

The difficulties of direct observation was overcome by Henri who applied the cinematograph to the microscope. This shows that the particle oscillates in a haphazard fashion about a mean position during a short interval of time.

THEORIES OF COLLOIDS

There are four accepted theories relative to the formation of colloids. Many colloidal solutions prove themselves to be mechanically inseparable since they pass through filter paper even if slightly. Nevertheless the lack of homogeneity can be shown by the use of ultra-microscope and it is by this instrument that we have been able to study colloids with better results than was formerly possible. We know that liquids containing particles of 20 $\mu\mu$ (1 $\mu\mu = 10^{-6}$ mm. or 1 $\mu\mu = 0.000001$ mm.) appear clear, and that turbidity first issues, only when the particles of about 100 $\mu\mu$ in magnitude are present. The solution theory suggests that colloids have exceedingly large molecular weights. The osmotic pressure likewise is exceedingly small in proportion to the quantity of the substance present, being so small in many cases that it cannot be measured. Inasmuch as the osmotic pressure bears a ratio to the number of molecules this led to the assumption of a small number of molecules and therefore a very great weight to each. The following table lists the molecular weight of a number of common colloids.

Molecular Weights

Hydrogen	0.1×10^{-7} cm.	(Size)
Methyl Alcohol	0.5×10^{-7} "	"
Chloroform	0.8×10^{-7} "	"
Glycogen	1,625	
Ferric Hydrate	6,000	
Tungstic Acid	1,750	
Egg Albumen	14,000	
Starch	25,000	
Tannin	2,643-3,700	

The large molecules explain the lack of ability to pass through animal membranes, for the reason that the molecules are too large to pass through the partition pores; also the gel formations may be viewed as a meeting of the already large molecular complexes present, forming still larger microscopic aggregates which become visible. Colloidal particles have a marked tendency to cleave firmly to one another and to form bodies; a property which is very advantageous. In all colloids we see foam formation when the substances in the colloidal state, together with free alkali or free acid, are mechanically agitated; in the organic colloids in a marked way in soap and protein; and in inorganic colloids; in talcs, when they form silicon hydroxides in contact with water and dilute hydrochloric acid.

By the absorption theory a number of properties can be explained. According to that theory, sols are not ordinary solutions; but contain a phase of molecular complexity, distributed through the dispersing medium. This explains the essential deviation from the crystalloidal sols, that is to say, the absence of osmotic pressure, lack of diffusion and electric conductivity.

The suspension theory was perhaps the first view taken in reference to colloidal theory and has later been proven conclusively true. It assumes that minute particles are suspended in an extremely fine state of subdivision. Colloidal gold contains minute gold particles from 60 $\mu\mu$ to 6 μ in diameter There are solutions whose particles are too small to be measured, but by passing a beam of light through the solution the presence of turbidity can be observed, which proves conclusively that the solution contains something in suspension. The ultra microscope informs us only as to the presence of the particles in the colloidal solution, and does not enlighten us relative to the exact relations and conditions of the separate particles.

The crystalline theory, which is in reality only a furthering of the suspension theory, holds that the colloidal particles are crystalline. It assumes that the crystalline state is the only possible state for matter and accordingly solids, liquids and gases are crystalline. This has a substantial background for many optical properties separate the assumption of a crystalline phase, as for instance, the scattering of colloids in the ultra-microscopic image.

COLLOIDS IN BIOLOGY AND MEDICINE

Colloids and their properties are of special interest to the student of biology since the cells of all living organizations are made up of chemical substances known as protoplasm, the structure of which is due to colloids. The sun throws down heat on the green foliage of the leaves, decomposing the carbon dioxide into carbon and oxygen. The free oxygen is returned to the air in an unknown way and the carbon is worked up into substances in the colloidal state; especially to starch. The heat of combustion of starch to carbon dioxide in water amounts to 4,123 calories per gram, therefore the same amount of energy, by the laws of the thermodynamics, is necessary to form starch from carbon dioxide and water. Since the reduction of carbonic acid gas occurs in sun light, this radiant energy must have been furnished by the sun.

Colloidal solutions may be prepared which are only slowly influenced by a change in external conditions. The passage of a hydrosol into a hydrogel may be preceded for a long time by a metastable condition of the colloidal solution. The forms assumed by the depositions or growths from such slowly changing metastable colloidal solutions sometimes closely resemble the lowest form of living organisms. The metastable colloidal solutions may be prepared from ferric nitrate and sodium silicate in such proportions as to give a slight deposit after boiling for ten minutes. The solutions then contain two metastable colloids: ferric, hydroxide and silicic acid. On the other hand, those completely deposited do not form growths. The colloidal solution is then placed in sterilized tubes which after being hermetically sealed is heated in an autoclave for 15 minutes at 110 deg. C. Micrographs after 7 months showed growths in the tube which consisted of (1) particles sometimes fine and sometimes coarse granular deposits with fine fibers running in them. (2) Chains of dots sometimes slightly elongated. (3) Branching coarse fibers resembling cotton fibers. (4) Exceedingly fine fibrils sometimes forming a net work like a fibrine network. At other times they are single and convoluted into the most intricate knots or loops. When stained with methymlene blue dye, they do not give the reaction with iodine and sulphuric acid for cellulose. The living cell is built up of metastable colloids but nothing can be observed which can be described as a living organization arising from the inorganic solids and it was found impossible to subculture any of the growths in other media.

Colloidal chemistry is by no means a new subject. The properties of colloids have long been made use of, but only during recent years has work been done on colloids from a theoretical standpoint. The early Chinese potters knew something of colloidal properties, as shown by the manner in which they allowed their clay to "age" or become more plastic. The ancient Egyptians were skilled in the art of cement making, which far exceeds any work which has been done at the present. Their pyramids have withstood the elements for 5,000 years and are today many of them in excellent state of preservation.

The evolution of the photographic plate serves as a striking example of the use of gelatine and similar colloids in the arts and industry. In the very familiar operations involved in cooking, brewing and dairying, colloidal solutions are always appearing and operating under definite laws. It is probable that no other substances are more interesting from the colloidal standpoint than common clay. It is the mineral part of the soil, composed of rocky material and complex silicates containing iron, aluminum, calcium, carbon dioxide and the phosphates. In the manufacture of cements and porcelains, in the purification of water and in the treatment of various soils; colloidal properties come of the first importance. The setting of cement is thought to be due to the coagulation of the hydroxides of silicon, aluminum anl iron and the action of carbon dioxide in forming after a time, hardened calcium carbonate. The gravel acts only as neuclei about which the coagulation takes place. Many more examples could be cited to show the intimacy which colloids hold in our most familiar chemical problems, and it is a praiseworthy fact that at the present time so much time and study are being spent seeking after their hidden secrets.

BANISHING GERMS WITH A SILVER SPOON

RECENT investigators have established the fact that certain metals have a definite sterilization effect when present either in mere infinitesimal traces or possibly by some sort of transmitted effect. The celebrated botanist, Naegeli, was one of the first to prove this by the following experiment: A glass flask in which a few copper coins had previously been lined was filled with water after the removal of the money. After a short time a number of algae were observed clinging to the sides of the flask, but strange to say those portions of the glass against which the copper coins had rested remained entirely free from such a growth. When these portions of the surface were tested for copper with chemical agents, however, no trace of the metal was discovered. For this reason Naegeli assumed that this curious phenomenon was due to some hidden or latent power.

Quite recently, however, an Austrian physician, named Saxel, has repeated this experiment using silver instead of copper. He found that it was possible to completely sterilize water merely by placing a silver spoon in it; in fact a glass vessel once treated in this manner even retains its germicidal power. Yet not the slightest trace of dissolved silver was to be found in the water. For this reason Dr. Saxel came to the conclusion that the action in question cannot be ascribed to any known chemical or physical cause, but must depend upon some force capable of acting at a distance. Certain other investigators have discovered in the meanwhile that extremely slight traces of dissolved metal exert an inhibitive action upon the development of bacteria, for example, copper sulphate acts as a bactericide even when so dilute that the solution contains only one-fifty-millionth of the salt.

Another German scientist, Professor Bechhold, has recently pursued this matter and has described his results in *Umschau*. He was able to prove that glass vessels which had contained either nitrate of silver, calomel, or chloride of mercury, could not be used to grow germ cultures no matter how carefully washed, until they were boiled in nitric acid. His conclusion was to the effect that there is in general no such thing as a completely insoluble substance, but that in some cases our means of testing them are not sufficiently delicate to discover extremely minute quantities. To prove his point he performed a remarkable experiment, by means of which he succeeded in making visible to the eye the solubility of substances in spite of the fact that ordinary physical chemical means cannot detect such solubility. He began by forming cultures of staphylococcus upon agar-agar in vessels of hard glass. After the congelation of the agar-agar small disks of filter paper were placed upon it and a silver coin laid upon each disk. The filter paper was then coated with so-called insoluble silver compounds, such as sulphide of silver, iodide of silver, chloride of silver, oxide of silver, bromide of silver, silver chromate, silver carbonate and silver oxilate, this being done before the introduction of the disease germ. The staphyloccocus cultures were then kept in a dark room at the ordinary temperature for four days. This was in order to prevent the development of the bacteria at the same time that it gave an opportunity to allow the supposedly insoluble substances to become diffused in the agar-agar in case, as the experimenter suspected, there was really some slight capacity of being dissolved.

The culture vessels were then placed in an incubator and allowed to remain for twenty-four hours, whereupon their examination showed the following curious results. Not only surrounding the silver coins but also in the vicinity of the paper disks smeared with the so-called insoluble silver compond, there were spaces entirely free of bacteria, although all around these spaces the germs were growing luxuriant. The obvious deduction is that traces of the compounds had been dissolved and passing into the culture medium had killed the germs within a definite radius. The only exception was in the case of silver sulphide, which was not surrounded by a free zone as was the case of the others. The width of the free zones accorded with the solubility values of the substances concerned found by other methods. However, the lack of a free zone around the silver sulphide disk is easily comprehended when we learn that one liter of water dissolves only 0.000,000,000,000,000,010.

This extremely valuable experiment throws a definite light on the successful result obtained in infectious diseases by means of colloidal silver and the admirable effects obtained by means of treating wounds with silver foil. It is possible by this means also to make a comparative study as to the germicidal effect of various substances, thus rendering the art of disinfection more definite than it has hitherto been.

Detecting Poisons in Food Substances*

Chemical, Biological and Quantitative Analysis of Foods to Detect Toxic Substances

By Émil Kohn-Abrest, D.Sc.

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IN order to determine the value of any given food material it is necessary to obtain chemical, biological and mathematical information with regard to it. "Alimentary mathematics" has become in fact a distinct branch of mathematical science dealing with such questions as the calorific equivalent and the amount of energy produced or work done by any given dietary ration. Such a determination also involves the obtaining of toxicological information with regard to the substances employed, and it is with the latter department of the science that it is my purpose here to deal.

But first let me inform my readers that there is in France an institution which is unique throughout the entire world—an institution in which all those questions relating to food substances are studied on the most extensive scale. I refer to the *Scientific Society of Alimentary Hygiene and the Rational Alimentation of Man.* This establishment was founded in 1904 and is located not far from the Pantheon at 16 Rue de l'Estrapade.

This society which is under the direction of the most eminently well fitted social and scientific authorities undertakes, among the other tasks which it has set itself, to diffuse among the general public all possible ideas which are of value in domestic economy. Its labors in these directions have been followed and encouraged by the public authorities.

Among those questions which have more particularly occupied the attention of this society since its foundation and which touch on the domain of toxicology from certain points of view, I may mention that of the chemical composition of foods.

Any food substance in order to be normal, *i.e.*, to be habitually suited for ingestion in human organism, should leave within the body nothing which is either injurious or useless; in other words the said food must contain no chemical element other than those comprised in the human body.

The eminent French chemist, M. Gabriel Bertrand, has calculated that a man having a supposed weight for example of 100 kilograms is composed of the following chemical elements:

	Kg.		Kg.
Oxygen	62.810	Sodium	0.260
Carbon	19.370	Potassium	0.220
Hydrogen	9.310	Chlorine	0.180
Nitrogen	5.148	Magnesium	0.040 or 1/2.500
Calcium	1.380	Fluorine	0.007 or 1/16.000
Sulphur	0.640	Iron	0.005 or 1/20.000
Phosphorus	0.630		

It is a simple matter to calculate according to this table the composition of the smallest "gross weights."

Most of the oxygen and hydrogen in the human body are combined to form water; thus in a man weighing 100 kilograms there are 60 kilograms of water consisting of 6.67 H and 53.33 O. Thus if our bodies were desiccated 60 per cent of us would evaporate and there would be left a residue corresponding to that of the mummy of a Pharaoh or to the "living corpse" in Edmond About's famous romance of *The Man with the Broken Ear.*

The rest of the oxygen and hydrogen in the body is combined with nitrogen and carbon to form the so-called organic matter which composes the various tissues of the body. Iron is found in the blood, being the active principle in the haemoglobin of the red corpuscles. Other mineral elements are found in the bones: calcium, phosphorus, phosphoric acid, etc. Phosphorus is also found in the brain in the form of lecithine, while sodium and chlorine are combined to form common salt (chlorine of sodium).

Other elements exist in the body in very small proportions or mere traces, yet these minute quantities are none the less useful to the organism, where they serve as centers of activity for nutrition and other forms of metabolism.

For example, Dr. Gyaya, a Serbian chemist, working in the laboratory of toxicology in Paris, has recently discovered that the amount of zinc found in the human body increases with age, varying between 60 and 350 mg.; there are also present a few centigrams of copper, a few milligrams of silicon, traces of aluminum, and one or two milligrams of iodine and of bromine. . . . Finally, there are one or two millionth parts of lead, a faint trace of manganese and minute amounts of arsenic, not more than one twenty millionth part of the total mass of the human body.

In their natural state farinaceous materials as well as mollusks, fish, and fresh vegetables, contain not merely traces of copper, zinc, and boron, but sometimes quite astonishing percentages of these elements. Oysters, for example, are quite rich in copper and in zinc; in a kilogram of the flesh of green *marennes* there are 138 mg. of copper and 1.157 mg. of zinc. As for boron, the total amount taken in per person per day is no less than 30 mg. in a normal diet, and about the same figures hold true for fluorine. The amount of lead taken into the system daily by means of food is extremely minute, on the contrary, being less than 1/10 of a milligram, while as for "alimentary" arsenic, not more than 1/50 of a milligram is absorbed in the course of 15 years, an amount which is absolutely insignificant with regard to its effect as a poison.

ANTISEPTICS AS ADULTERANTS

In my opinion the use of so-called *antiseptic substances* is the chief cause of the introduction into the human body and excessive accumulation therein of elements which are either quite useless or actually injurious to the organism. . . . It is possible to preserve food materials without the use of chemical substances, by such methods as desiccation, sun-drying, pasteurization, boiling with subsequent exclusion of external germs, etc. All of these processes are purely physical and introduce nothing injurious into the food. With regard to antiseptic substances, however, there are only three means of preserving food by chemicals which are permissible from a hygienic point of view. The best known of these is salting, in which case the food is treated with cooking salt or else preserved in strong brine. Food can also be preserved by saltpeter which imparts to smoked tongues and other meats hues more brilliant than those of nature. Finally, *sulphurous* acid has always been employed for the preservation of wines and other drinks. These are the only antiseptic substances tolerated in France for the conservation of foods, the last mentioned being restricted to beverages alone.

Forbidden to our cuisine are such things as borax, boric acid, the fluorobates, sodium fluoride, salicylic acid, benzoic acid, formol and hydrogen peroxide, to say nothing of other substances which include even a number of very violent poisons! These substances do, indeed, insure the preservation of food products by killing microbes; but while arresting injurious fermentations they also interfere with those desirable ones which are involved in the process of digestion. While antiseptics may possibly be suffered by organisms which are extremely sound and healthy they undoubtedly have an ill effect on the digestive and renal functions of more delicate subjects.

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Finally, our authorities on hygiene also object to the use of antiseptics because they lend themselves so admirably to deceiving the buyer by masking the degree of alteration which perishable foods may have undergone previous to their preservation. It is a regrettable fact that in certain countries the authorities upon hygiene exhibit more tolerance than do those of France. Thus in the United States the use of boric acid and borates is permitted in the packing of meats and egg powders, while sulphurous acid is employed in the preparation of certain dried fruits such as apricots. Australian producers, to mention another instance, are allowed to export borated butters.

Among chemical substances possessed of a powerful antiseptic action, chlorine and its derivatives, together with ozone, form an exception to the rule in one particular instance, *i.e.*, when they are employed not to preserve food but to *sterilize water*.

Water, indeed must be regarded as one of the most important of alimentary substances. The ideal method of sterilizing water is by means of ozone, since this merely introduces the oxygen normally found in properly aerated water. Chlorine is less attractive; however, when such a water supply as that of Paris is concerned it can be sterilized by contact for 30 minutes of one demi-milligram of chlorine with one liter of water.

POISONOUS METAL ALLOYS

Food can readily be made unfit for use by contact with alloys of lead or other poisonous metals. This accounts for the rigid regulations in force with regard to the quality of the tin plate of which cans are made and of the solder employed in sealing them; the tin used in covering the sheet iron must be 97 per cent pure, with not more than 0.5 per cent of lead and 0.01 of arsenic present. Solder used inside the cans must likewise be made of equally pure tin. For outside soldering, however, a solder compound of 2/3 tin and 1/3 lead is permissible. It may happen, however, in case of defective workmanship that a drop of this external solder may penetrate the can and thus expose the consumer to the danger of lead poisoning. Thus we see that the sealing of containers for food is a matter requiring the greatest care. It has been proposed to avoid such accidents by stamping or pressing in the cover or sealing them by means of rubber gaskets, but curiously enough the latter are made of rubber combined with red lead, which is the exceedingly poisonous substance, *lead oxide*.

Lead and its salts when ingested produce in the course of time such serious disorders as "saturnine" colics, paralysis, jaundice, hemorrhages, etc.

But as it happens lead and its salts are very soluble in canned foods—particularly so in sardines packed in oil.

The following table prepared by the late distinguished French chemist, Armand Gauthier, shows the percentages of lead which may be found in canned goods whose containers are defective (the figures given representing milligrams of lead per kilogram of food):

Green peas	2.8	Sardines in oil	45.0
Green beans	2.0	Mackerel in oil	49.0
Salmon	30.0	Tuna fish in oil	30.0
Pate de foie gras	11.8	Lobster	27.0

I may add that while the taking into the system of a few milligrams of lead in a single instance may not be attended with serious results, a long continuation of such a diet inevitably produces a serious or even fatal case of lead poisoning. For this reason when water is taken from lead pipes a considerable quantity of water, at least several liters, should be allowed to flow before any is used. On the same principle the first few drops should be rejected when a siphon of aerated water is opened. It is somewhat reassuring, however, that water from natural springs dissolves lead less than either filtered water, rain water, or distilled water; the solvent action is favored by contact with the air.

Another source of lead poisoning is in the use of utensils containing lead in the preparation of salads since the acetate of lead may be produced by the juice of fruit or even by a marinade of game. Indeed some accidents have occurred through the shot used in killing game coming in contact with such acids as vinegar, etc.

ARSENIC IN FOOD STUFFS

Arsenic is even more dangerous, especially in the form of *arsenious* acid. But arsenic is one of the most frequent impurities in a long list of chemicals. Unfortunately the disturbed conditions which prevail at the present time have made it more difficult than before the war to obtain pure chemicals, but there is a direct relation between the amount of arsenic in certain chemicals and that found in certain foods. In many of the industries concerned in the preparation of food products for the market there is an extensive use of chemicals—e. g., in sugar and glucose refineries, among vintners, and by manufacturers of soups, beef cubes, etc. In the making of glucose, for instance, sulphuric acid is used to change starch into glucose; hydrochloric acid is employed to assist in the solubilization of the active principles of meats from which extracts and broths are to be made; sulphate of lime, or plaster, is sometimes used by vintners and sodium sulphite to make beer "keep," etc., etc.

For these various reasons I have undertaken during recent years, in association with M. Bouligaud, to make a control examination of the purity of chemicals and of traces of arsenic. These researches have proved that arsenic is sometimes present in food products in amounts which must be regarded as alarming when we recall that some forms of this metalloid are fatal to man in doses of only 10 centigrams.

Table I on the next page prepared by Jadin and Astrue shows the amounts of arsenic found normally in plants—amounts vary according to the locality where grown:

As this table shows arsenic is normally *present only in a few thousandths of a milligram per 100 grams* of vegetable substance—a percentage absurdly small with reference to possible toxic effects. Moreover, as shown by Table II, page 327, giving the average amounts of various foods consumed daily in France in 1914, the amount of arsenic ingested in a normal diet is only about 21 thousandths of a milligram per day, or 7.66 mg. per year. The arsenic thus taken into the system is almost entirely eliminated with other waste matter. Yet the vigilance that is required is illustrated by the fact that in 1900 there was an actual epidemic of arsenical poisoning among beer drinkers in Manchester with no less than 4,182 cases, 300 of which were fatal. And these results were due merely to the fact that the brewers had used, for the purpose of fermentation, glucose which had acquired a toxic character from the fact that the sulphuric acid employed in their preparation had contained an undue percentage of arsenical impurities. In this connection it may be remarked that these glucoses are commonly used in the making of pastry and preserves of second grade. Apropos of this it is worth noting that sulphuric acid is itself prepared from iron pyrites (iron sulphide) in which arsenic is the impurity most frequently present.

In beer the traces of arsenic present should not exceed one or two tenths of a milligram per liter—less than the amount permissible in wine (the former being generally consumed in larger amounts).

In our preceding remarks we have dealt with hundredths and even millionths of a milligram—but we have no balance sensitive enough to weigh even the hundredth of a milligram—how then can such slight traces of arsenic be detected in food? The problem is exceedingly delicate, especially since the arsenic is usually so closely combined with the food that it is necessary to destroy the organic material which composes the latter in order to set free the former, while at the same time avoiding the loss of the arsenic through volatilization.

For example if a piece of meat is suspected—100 grams of it

is put through a meat chopper and the pulp is then placed in 35 cc. of a solution which contains about 7 grams of pure crystals of nitrate of magnesia to which there have been added a few pinches of calcined magnesia to prevent acidity, which would favor a loss of the arsenic. The mixture is then heated in an oven to about 250 deg. cent. and then allowed to stand for 3 hours. During this time the mixture is dried and also undergoes torrefaction, so that the organic matter enters into an intimate union with the magnesia forming a sort of spongy amadou or "tinder"; the capsule containing this mixture is then put in a special furnace heated to a dull red glow. Here it is completely calcined in 20 minutes, all of the organic matter being consumed without any loss of the arsenic, the entire amount of the latter having combined with the magnesia to form a compound which is highly resistant to heat—magnesium pyro-arseniate in which the arsenic can readily be detected. A more rapid process of analysis can be employed, provided it is possible to allow for a small loss of the arsenic through volatilization—a loss insignificant where arsenic is present in toxic amounts. In this process the product is diluted in the solution of magnesium nitrate, rapidly evaporated and calcined directly at a higher temperature after the addition of a small amount of nitric acid. By this method the result is obtained in a few minutes.

TABLE I.—ARSENIC IN FOODS

FOOD MATERIAL	ORIGIN	Contents of Arsenic in Thousandths of a Milligram per 100 gr. of the Substance.
CULTIVATED		
1. Mushrooms	Vicinity of Montpellier	6
2. Black truffles	Vaucluse	20
Dry Vegetables		
3. Rice	Japan	7
4. Red haricot beans	Unknown	25
5. White haricot beans	"	10
6. Chick peas	"	9
7. Split peas	"	26
8. Lentils	"	10
Fresh Vegetables		
9. Artichokes	Vicinity of Montpellier	10
10. Salsify	"	7
11. Chicory	"	10
12. Prickly artichoke	"	9
13. Lamb's lettuce (Valerianella olitoria)	"	9
14. Lettuce	"	23
15 Spinach	"	9
16. Pumpkin	"	3
17. White kidney beans	"	20
18. Green peas	"	4
19. Celery	"	20
20. Carrots	"	5
21. Radishes	"	10
22. Water cress	"	12
23. Cauliflower	"	8
24. Wild asparagus (tips)	Calc. Garrigues of Montpellier	10
25. Leeks	Vineyards	3
Dry Fruits (Edible Part)		
26. Walnuts	Lozère	13
27. Hazelnuts	Larzac	11
28. Almonds	Vicinity of Montpellier	25
29. Dates (Var. Déglet and Beida)	Algeria	12
Fresh Fruits (Edible Parts)		
30. Chestnuts	Le Vigan	5
31. Apples (Var. Reinette)	"	5
32. Pears (Var. Royale)	Spain	7
33. Oranges	"	11
34. Mandarins	Blidah	12
35. Pineapples	The Azores	8
36. Bananas	"	6

Our next task is to detect the arsenic contained in the ash. The latter is dissolved in a small amount of water acidulated with sulphuric acid, after which the liquid is introduced drop by drop into the well-known apparatus invented by Marsh, which is merely a hydrogen generator. If the slightest trace of arsenic enters this apparatus the highly toxic gas known as *arsenuretted hydrogen* will be produced; this gas has the odor of garlic and can readily be distinguished from pure hydrogen. The apparatus is provided with a glass tube having a rather small bore and drawn out at one end so as to be very narrow. The hydrogen escaping from the aperture at this end of the tube is lighted, and in case it contains any arsenuretted hydrogen the arsenic will be condensed on the cold wall, forming thereon mirror-like spots. By placing a saucer in front of the flame at regular intervals a number of spots can be obtained, each of which contains 1 or 2 hundredths of a milligram of arsenic. However, it is no longer the custom to form these spots, since this involves a considerable loss of arsenic. *Rings* are produced instead; to do this it is only necessary to apply (through the glass tube) sufficient heat to the gas at the point where it is liberated and to cool the end of the tube. . . . A ring of metallic arsenic will thus be deposited on the cold portion of the tube—the more arsenic the bigger the ring deposited.

TABLE II.—AVERAGE CONSUMPTION OF ARSENIC IN FOODS IN FRANCE

DAILY RATION OF FOOD	Average consumption per Day in Grams	Content of Arsenic in This Quantity in Thousandths of a Milligram	Content of Arsenic in 100 gr. of the Substance in Thousandths of a Milligram
Bread	420	2.9	0.69
Boned meat	180	1.8	1.0
Fish	35	4.3	12.9
Eggs (minus shell)	24	0.05	0.2
Leafy vegetables	250	0.5	0.2
Potato	100	1.12	1.12
Milk	210	0.1	0.4
Wine	518	2.9	0.5
Sea salt	10	2.3	23.0
Drinking water	1,000	5.0	0.5

HYDROCYANIC ACID IN BEANS

Some 15 years ago there was offered on the Bourse a cargo of "Java" beans at just half the price of our good French beans. But having aroused suspicion they were analyzed and found to contain prussic acid! They proved to be the horrible "Java peas," a variety of the *Phaseolus lunatus* which was studied in 1901 by the English scientists, Dunstan and Henry; . . . as its name implies this bean is crescent-shaped in contrast to our own haricot beans which are somewhat ovoid in shape. The Java beans also have a somewhat bitter after taste which is lacking in our beans. For this reason they can be detected by chewing one of them, which is not dangerous. However, they can also be detected by a very simple chemical process devised by Professor Guignard and based upon the property possessed by certain papers impregnated with colored reagents of changing color under the influence of acids.

There are numerous varieties of the *phaseolus lunatus*, found not only in Java but in Madagascar, Reunion, the Cape, etc. While the degree of toxicity varies, they all possess the com-

mon property of yielding prussic acid merely through maceration in cold water. The most poisonous among them are those called Java peas, bitter peas, kratock peas, or Achery peas. In a single lot of these seeds variously shaded and striped, I have found some which yielded as much as 3 gr. of hydrocyanic acid per kilogram of peas, *i.e.*, enough to kill 60 people. Other varieties of the *phaseolus lunatus* yield only from 1 to 3 decigrams per kilogram of hydrocyanic acid; these include especially the red or white haricot beans from Burmah, a variety in which the seeds are, in general, smaller and thicker than Java peas. Finally, a more cultivated variety also exists which yields only a few centigrams of hydrocyanic acid per kilogram; namely, the large white or pink haricot beans from Lima, the Cape, or Madagascar.

The government has formally forbidden the importation of haricot beans of the "Java peas" type and of all flour or other food products made from them. Burmah beans are tolerated on condition that the amount of hydrocyanic acid does not exceed 200 mg. per kilogram of the seeds or materials made from them, but in reality this limit is too high. The ration of beans often amounts to about 100 gr. per day and it would be far from prudent to consume very often such large quantities of a product containing such a percentage of prussic acid, especially when the water in which they have been soaked has not been thrown away. Hygienic authorities, therefore, have advised that the permitted percentage of prussic acid per kilogram should be reduced from 200 mg. to 100 mg. If this were done it would result in the exclusion of Burmah beans as food products. English experiments have shown that the third class of beans imported both from the Cape and from Madagascar, including both white and red, can be used as food without inconvenience. Among other food plants containing prussic acid I may mention the manioc from which tapioca is made. However, most of the manioes from Brazil or from Reunion yield such small amounts of prussic acid, only a few milligrams per 100 grams, that they are not dangerous.

Hydrocyanic acid does not exist in the *free* state in these exotic beans. It proceeds from the splitting up of those chemical compounds known as glucosides. All of these have the common characteristic of undergoing in the presence of water a special sort of decomposition called *splitting* or *hydrolysis* in the course of which they liberate various substances besides the glucose from which they derive their name. But in order for this hydrolysis to be produced some other special agent must be present, either a mineral acid or a "ferment" called a *diastase*. In the absence of water the glucoside and the diastase will not react upon each other. But as soon as these two substances come in contact through the *soaking* of beans which have been more or less bruised this hydrolysis is effected and the glucoside is then decomposed into glucose, alcohol (or acetone), and *hydrocyanic acid*.

While the diastase does not resist heat the cooking of beans is not enough to destroy their toxicity. In the first place it is difficult entirely to destroy the ferment by boiling, and in the second place the toxic glucoside does resist heat, so that when ingested even without the diastase it is sure to find in the intestines ferments capable of causing its injurious decomposition.

It is by a mechanism of analogous nature that prussic acid is produced in many other vegetable products, such as the leaves and fruit of the cherry laurel and the fruit and kernels of the prune, apricot, cherry, etc., as well as in bitter almonds.

The amount of hydrocyanic acid set free by the action of water upon the kernel of the stones of peaches, plums, etc., is very variable. . . . A case is known in which a small child died from having eaten just 2 kernels of peach-apricots.

When bitter almonds are macerated the amount of hydrocyanic acid set free varies from 1 to 20 per cent; 5 or 6 bitter almonds are enough to cause the death of a child. The percentage is still higher in cherry stone kernels, as much as 3.5 gr. of HCN having been obtained from one kilogram. Thus "kirsch," the excellent brandy obtained by distilling cherries, contains, besides the "quetsch" and the "prunelle," hydrocyanic acid; from 30 to 100 mg. per liter have been found on analysis—this, to be sure, is an inconsiderable amount, but adulterated kirsch and certain artificial kirsches made by macerating the fruit of the cherry laurel in alcohol, etc., may contain much larger amounts of HCN.

THE CONVERSION OF SAWDUST INTO CATTLE FEED

RECENT investigations carried out at the Forest Products Laboratory indicate that the sawdust of coniferous woods can be converted into a wholesome cattle feed.

The process for preparing such cattle feed depends upon the conversion of part of the wood into sugar by cooking it for about fifteen minutes with a dilute acid under 120 lb. pressure. In this treatment about 20 per cent of the wood is converted into sugar and the remainder rendered more digestible. The sugars are then extracted from the digested dust with hot water, the acid is removed from the resulting solution by neutralization, and the liquor is evaporated under reduced pressure to a thick syrup. The concentrated sugar solution thus obtained is then mixed with the residue left after cooking and the whole is dried to less than 15 per cent moisture content. The finished material is darker than the original sawdust, is very brittle, and contains a larger proportion of fine dust.

A preliminary feeding trial, using a product prepared in this way from Eastern white pine, was conducted by the Wisconsin College of Agriculture with favorable results. Three cows were fed by the reversal method for three periods of four weeks each. In the first and third periods they were given an excellent ration, consisting of alfalfa hay, corn silage and a concentrate mixture of 55 parts of ground barley, 30 parts of wheat bran and 15 parts of linseed meal. In the second period hydrolized sawdust was substituted for part of the barley, 2 lb. of sawdust being fed in place of each pound of barley, as it was not expected that hydrolized sawdust would have as high a feeding value, pound for pound, as barley. The mixture used during the second period contained about 26 per cent of hydrolized sawdust. At no time was any difficulty experienced in getting the cows to clean up this concentrate mixture. The cows maintained their production of milk in the second period as well as in the first and third and showed an appreciable increase in butter fat production. A decided increase in weight was noted during the period in which they were fed the treated sawdust.

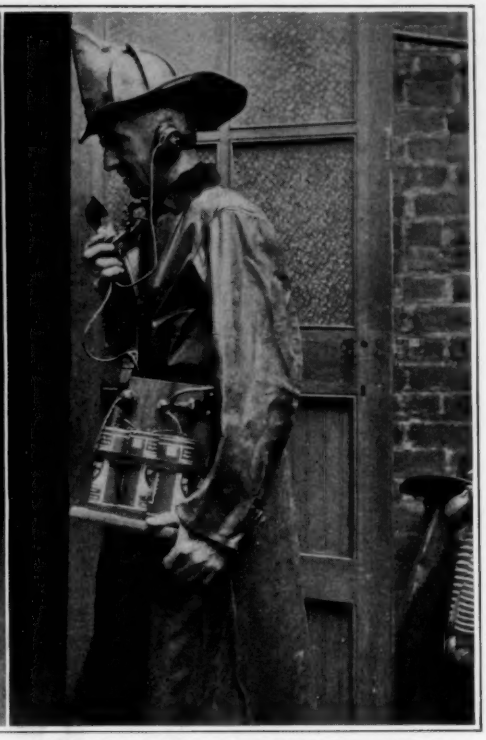
While no definite conclusions can be reached from this brief trial, the results do show that cattle may be fed a limited amount of hydrolized sawdust with beneficial results. It should be pointed out that hydrolized sawdust contains only a negligible amount of protein and that it must necessarily be fed in conjunction with other nitrogen-containing materials. In both rations used in this trial plenty of protein was furnished by the other feeds used.

We wish to emphasize the fact that these experiments are preliminary and that as yet the laboratory is not in position to advise as to the commercial application of the process. Further trials will be carried out to furnish additional data on the feeding value and methods of preparation.—From *Chem. and Met. Eng.*

SUBSTITUTE FOR MILK AND CREAM

A PATENT has been granted to G. D. Thevenot, U. S. 1359633, Nov. 23), on a liquid food simulating cow milk. It is prepared by cooking soy beans until softened and sterilized and the coloring matter has been removed, separating the free liquor and crushing the solid material to a fine pulp, mixing the latter with sterilized and slightly alkalized H_2O, digesting with proteolytic enzyme in the presence of NaCl, separating the H_2O and the material which it carries in solution and suspension, and adding to it fats, oils and sugar.—*Chemical Abstracts.*

AS A LAST RESORT SHOOTING A LIFE LINE UP TO PEOPLE TRAPPED IN A BURNING BUILDING



OFFICER TALKING TO FIREMAN EQUIPPED WITH A TELEPHONE HELMET

Modern Fire-Fighting Equipment

How Our Firemen Meet the Ever-Growing Problems of Fire Prevention and Control

By Robert G. Skerrett

Photographs Copyright by Keystone View Co., Inc.

FIRE worshippers we are not; and yet how many of us realize the tribute paid yearly in this country to devastating flames?

Each twelvemonth the material and mortal sacrifices due to conflagrations reach staggering totals; and still we deem ourselves quite up to date. According to the latest figures available, fully 15,000 persons are burned to death and 17,000 others are hurt by fire annually. The property losses from the same fundamental cause aggregated in 1919 not less than $325,000,000. In the course of each week substantially 890 dwellings are thus destroyed right along; and the worst of it is, so it is authoritatively stated, 65 per cent of these fires are of trivial and preventable origin.

During the last decade we reared more than $900,000,000 worth of new buildings, but within that span structures representing a loss of a quarter of that sum went up in smoke. Modern conveniences abused have, unfortunately, levied their toll in this way. For example, two years ago, property to the value of well-nigh $15,500,000 owed its destruction primarily to electricity; and the careless handling of the electric iron was responsible for 46 per cent of that damage. The heedless disposition of lighted matches and burning cigars and cigarettes stands out conspicuously in the causal records of a great number of disastrous conflagrations.

These data are given in order that the average citizen may grasp the burden that is now placed upon the fire departments of our communities; and the more populous the city the harder the task confronting the fire fighters. Not only must these men smother the flames with all possible dispatch but it is equally incumbent upon them the while to minimize as far as practicable injury by water. In crowded business and industrial sections one good-sized fire may gravely affect the welfare of hundreds, yes, thousands, of persons and create economic disturbances of a magnitude far beyond that of the immediate property loss involved.

Not so many years ago, fire fighting, even in some of our principal cities, was little better than elemental in the methods and the facilities employed. Apart from the steam-pumping engines and various long-used equipment, success in the struggle rested in the main upon the splendid audacity and courage of the personnel of the fire departments. Dash and daring were the outstanding assets; and often these men paid the supreme price for their thrilling and reckless self-forgetfulness.

Today the trained fire fighter must be no less intrepid than his fellows of the days gone, but he is expected to exercise caution and cunning and to utilize agencies that add immensely to his powers of effective service. In short, fire fighting, like modern warfare, has its recognized strategy and its special weapons, and the work is more than a display of skill—it is proof of applied science and an education about which the average citizen knows but little. Many men and many minds are wrestling ceaselessly with the ever-present problem of fire prevention and fire control; the engineer, the architect, the chemist, the electrician, and the inventor are all contributing to the common cause of security. In order that we may bring to a focus what has been done in this field of protection, let us tell something about the fire-fighting equipment of the nation's foremost city.

Greater New York is probably unparalleled in the task it

presents to a fire department because of its densely populated districts and the prevalence of numerous towering structures. It is equally true that no other municipality the world over involves so tremendous a fire hazard by reason of concentrated wealth and its extremely diversified business and industrial undertakings. The advent of the skyscraper, the wide adoption of steel-framed buildings, and the presence of thousands of people in a single office edifice—not to mention relatively narrow streets—all combine to place obstacles in the paths of the

USING A CUTTING TORCH TO FREE A MAN CAUGHT UNDER AN ELEVATOR

fire fighters. Within its gates, the city of Greater New York has more than 5,600,000 residents, and a daily transient population somewhere in the neighborhood of half a million persons. Further, the assessed property valuations aggregate substantially $9,000,000,000.

In these circumstances, it is essential that the fire-fighting instrumentalities should be brought into play when needed with the least delay, and from the very nature of things this would not be feasible but for the development of truly up-to-date apparatus of divers sorts. Time and again conflagrations have broken out within the limits of the Greater City which have necessitated the concentration of the major part of the fire-fighting force upon a restricted area, and the men and apparatus have been drawn from districts five, ten, and more miles away. Remembering that weather conditions may seriously hamper street travel, much has depended upon bringing up reinforcements with celerity. As has been said by one eminent fire chief, "The most dangerous time at all fires seems to be the first thirty minutes."

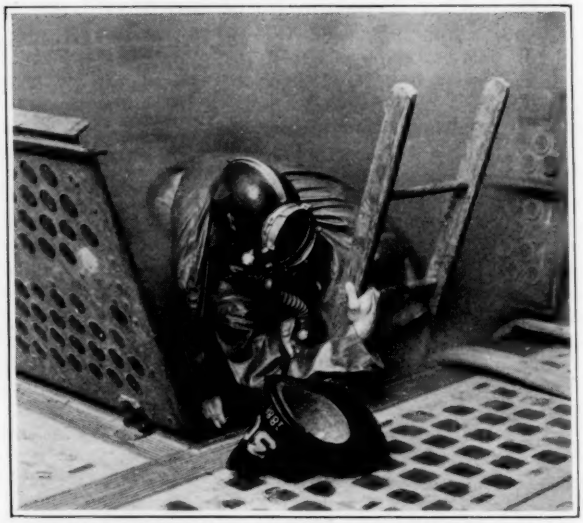
In order to deal with this critical period, steps were taken only a few years back to motorize the fire apparatus, and today well-nigh 66 per cent of the equipment is self propelled. This includes engines, hose wagons, hook-and-ladder trucks, water-towers, rescue wagons, fuel wagons, and cars for the fire chief. At the start, the steam engines were motorized by substituting gasoline tractors for the horses and the front wheels, which made it practicable to increase enormously the mobility of the existing engines. Latterly, however, there have been introduced gasoline propelled and pumping engines, which rely entirely upon internal combustion motors. These machines can each of them deliver 1,000 gallons of water a minute; and their operative economy is several hundred dollars lower per year than the erstwhile horse-drawn "steamers."

The automotive equipment can cover long distances at speeds ranging from 20 to nearly 40 miles an hour, and can negotiate grades at full tilt which would slow up to a walk the pace of the sturdiest of draft animals. For a straight-away run, horses reach their limit in about five miles, and from there on they become exhausted quickly even when street conditions are favorable. In an expansive city, when a raging fire calls for the assembling of many companies, every minute saved in getting to the point of attack is of vital concern. As a means for dealing with the fire needs of less thickly settled sections, the city has at its command what are known as combination hose wagons and chemical engines, and these "scouts" can tear along at a speed of fully 40 miles an hour.

These typically up-to-date agencies are provided with high-power gasoline engines, and carry two 35-gallon metal tanks charged with a chemical fire-smothering mixture. Within their operative zones, they are commonly the first to show up at a blaze; and in hundreds of instances they have been able to put the fire out before the heavier engines arrived. By their quickness of action they have succeeded in nipping conflagrations in the bud—thus preventing damage that might otherwise have totaled very large sums.

The effectiveness of the big gasoline propelled and pumping fire engine has been demonstrated in a spectacular fashion. Awhile ago one of these machines was connected by hose with the standpipe of the towering Woolworth Building and forced a stream of water to the fifty-eighth floor, 730 feet above the street, at which point it was discharged at a pressure of 67 pounds. The pressure at the engine was 450 pounds; and the fire chief declared that the powerful apparatus would have been able to drive the water to a height of 1,000 feet had piping of suitable size and length existed for that purpose. In passing, let it be said, that every tall building in Greater New York is provided with a standpipe system, with hose and hose connections on every floor—water being supplied by suitable pumps in the basement which charge tanks placed high aloft having storage capacities for thousands of gallons of water. The administrative personnel of these structures constitute an auxiliary fighting force, and their function is to bring into play immediately the facilities at hand and to battle with the blaze until the men of the city fire department come to take over the work.

The pumps of a skyscraper and the tanks feeding the standpipe and its branches can be readily reinforced by a very important link in the fire-fighting installation of the metropolis. At the outside of each of these structures there is what is termed a Siamese-twin coupling, which makes it possible



FIREMAN WITH SMOKE HELMET BRINGING OUT A COMRADE NOT THUS EQUIPPED FROM A GAS-FILLED SUBCELLAR

to join by hose the standpipe equipment with the high-pressure main running beneath the street. This main is part of a great circulatory system that has its impulse centers at strategically placed stations which draw salt water from the neighboring rivers. The high-pressure conduits cover the more densely occupied business districts of New York; and a veritable network of water mains traverses these areas, with hydrants rising from the pavement at frequent intervals.

When a fire alarm is sent in within these areas, the high-

CUTTING AWAY THE IRON BARS WITH A BLAUGAS TORCH TO FREE A MAN WHO HAS BEEN TRAPPED IN A BURNING BUILDING

USING A PULMOTOR TO RESTORE A FIREMAN WHO HAS BEEN OVERCOME BY SMOKE. HE WILL SOON BE READY TO RESUME HIS DANGEROUS WORK

pressure hose wagons and the water-towers are the first to respond. The hose lengths are coupled to the high-pressure hydrants, and the water is furnished in streams at a pres sure considerably greater than that generated by the regular fire engines. The water-towers rise many feet above the street level and make it practicable to throw their battering, quenching floods much higher or to direct them far into the depths of a burning building without the aid of ladders.

At each high-pressure station there are installed five electrically-driven centrifugal pumps, each capable of discharging 3,000 gallons of water a minute at a pressure of 300 pounds or 5,000 gallons a minute at a pressure of 150 pounds to the square inch. The entire equipment at the separate stations is controlled from a switchboard, and a single engineer has the whole plant at his command. Recording charts show him what is the drain upon the apparatus, and in this way he brings his pumps successively into action to meet the requirements of the firemen battling with the more or less distant blaze. At eight o'clock in the morning and at five o'clock in the afternoon, every day, even if there is no fire, the pumps are set in motion and run until the pressure is built up to 200 pounds. It is so maintained for thirty minutes for the purpose of testing the mains. Thus twice every twenty-four hours the engineers make certain that all is well with the distributing system.

Five years back the Fire Department of New York City made an important change when it secured three 1,000,000 candle power searchlights for use at night. Up to that time, the searchlights were installed upon the driver's seat and were energized by the steam engine upon which they were mounted. The cost of operation was not only very high but the light was unsatisfactory. In fact, the engines were hampered in their other service because of their searchlight outfit. The new searchlights are attached to water-towers; can be elevated where they will command a wide field; and besides giving much better illumination each of them actually nets a saving annually of $12,000. They are able to send their penetrating beams into a dark building or through a smoky atmosphere that would prove a veritable blanket to the rays of the lamps previously provided.

Not so long ago the firemen had nothing to guide them in groping about in an inky cellar or the darkened passages of a structure except an oil lantern. But now, thanks to the inventive genius of Thomas A. Edison, the men detailed for work of this sort carry portable searchlights energized by storage batteries. These lamps are of 1,000 candlepower, and are arranged to be attached to the front of the helmet or in any other position that is desirable. The firemen thus have both hands free and yet can count on the aid of far greater illumination than that of the less efficient and frequently hampering lantern.

Probably no section of the fire-fighting organization is more interesting than the Rescue Squad or "smoke eaters," as they are generally known to their associates. It was first called into being in 1915 for the purpose of meeting peculiar conditions at fires; and in a short while it demonstrated its value for such work as shutting off ammonia supplies when pipes burst in cold-storage plants; for entering and ventilating drug and chemical establishments during the progress of a blaze; for reaching the seat of a fire in smoky cellars and subcellars; for rescuing persons overcome by ammonia fumes or other gases; and for fighting fires where particularly pungent smoke prevails which renders the ordinary means at hand impotent. The adoption of the smoke helmets, with which the squad is supplied, was inspired by the activities of the U. S. Bureau of Mines in its life-saving efforts.

The rescue company is moved to the point of service by a specially designed motor car, and its equipment includes a Blaugas torch apparatus, two pulmotors, stretchers, a number of smoke helmets, extra cylinders of oxygen for the pulmotors and helmets, fire extinguishers, a life-line gun, axes, etc. The object of the Blaugas torch is to enable firemen to cut through steel rods or other metallic barriers in order to rescue persons trapped behind them or to get into places so as to fight the fire from a more advantageous position. In one test the Blaugas torch cut through a bar of steel 4 inches square in 63 seconds. Hack saws and files had taken more than an hour previously, to sever the iron window rods of a burning building. Similarly, the intense heat of the torch has been used effectively in clearing away the grill work and metal flooring of elevators to release persons held within or caught beneath the cars. Indeed, the mere summary of a year's activities of a rescue squad is interesting because of the diversified performances. For example, in one twelvemonth, the men donned their smoke helmets in 21 instances; employed the cutting torch on 7 occasions; brought the pulmotor into play 6 times; achieved rescues at 4 fires; removed bodies at 3 blazes; extricated people from elevators, etc., on 11 different dates; they raised the ladders at 3 conflagrations; forced doors at 21 fires; opened iron shutters at 8 calls; ventilated buildings by raising windows at 67 fires; ventilated structures through the roof at 34 fires; cut the roofs open at

8 fires; cut up floors at 3 fires; operated the lines at 12 fires; and did many helpful acts when scores of additional emergencies arose.

Time and time again the "smoke eaters" have carried hose into burning houses that could not be penetrated by the rest of the force. It is their practice to work in pairs so that they can assist and mutually protect each other. In particularly dangerous positions, one man goes ahead of his fellow to whom he is linked by a life line, and when this advance "smoke eater" fails to respond to the signal jerks, then his companion knows that he is in trouble and overhauls the rope until he is up to his stricken comrade to lend aid, which usually means dragging him out to the open air.

The speaking trumpet no longer suffices to spread orders and to facilitate communication amid the din and confusion of a conflagration—a much more dependable agency is available. The men of a rescue company are provided with portable telephone sets, and workers out of sight of one another can thus keep in touch vocally and report conditions for the better guidance of the other members of the fire-fighting organization. The public may not realize it, but there are times when the presence of certain chemcials makes it exceedingly hazardous to turn water loose upon them. A blaze might thus be transformed into a tremendous explosion. Therefore, the portable telephone enables the scouting "smoke eater" to reconnoitre and to send back word in time to avoid a possible cata[illegible]

There are occasions, when a blaze in intervening [illegible] renders it impossible to reach by direct means people trapped in the higher stories of a burning building. Their only salvation lies in getting a line to them that will permit their escape beyond the flaming zone. This is now effected by the life-line gun which looks not unlike a magnified pistol. A rod-like projectile is placed in the muzzle of the weapon, and to this is secured a light cord coiled in a canister. When the gun is fired the cord can be shot way aloft. In the hands of a qualified marksman it is entirely practicable to reach in this way the upper floors of a fairly tall structure, wherever people may be in peril. It is only necessary for some of them to haul in the cord and raise the while the life line which has been secured to it. The firemen, by practice, become decidedly expert in shooting the little rocket or rod to the chosen objective—be it a window, a balcony, or a roof.

It is not permissible in a mere sketch of present-day fire fighting to go into detail; but it is probably not an exaggeration to say that one of the prime features of any protective installation is the system of sending in fire alarms. New York City, after many bitter experiences, has wisely placed its signaling wires under ground, and has evolved facilities that supplement one another so that it is well-nigh impossible to prevent rapid communication and the dissemination of calls essential to dispatching successively needful reinforcements to battle with a blaze. According to the district and the nature of the fire hazard it presents, a single alarm summons fire-fighting forces of varying strength. Each alarm turned in goes to the "nerve center" of the fire-alrm system of the borough primarily concerned, and the telegraph dispatchers at headquarters send the alarm to the fire companies over two different wires. First the alarm rings on a small bell in the fire house and then, by means of the second circuit, on a gong in the station. The lesser bell gives the number of the station twice and strikes on every floor in the fire house. The big gong sounds the alarm once, beginning immediately after the signal has been completed on the small bell. The apparatus is generally dashing up or down the street before the large gong has finished its message. Therefore, the repetition of the alarm is virtually a precautionary measure to guard against any wire trouble on the first circuit. As soon as the alarm is sent out, one of the attendants at headquarters ascertains from a box of assignment cards the companies that are at the fire and registers them. These cards enable the operators to know the whereabouts of all of the companies at any moment.

When a box is pulled within a thousand feet of the river front two fire-boats respond in the borough affected and augment the land equipment. New York City's waterfront is about 577 miles in length, and 103 miles are developed and require fire protection. The dock property alone of the municipality represents approximately $180,000,000; and fully two-thirds in value of all of the imports of this country enter through the Port of New York. Therefore, the fire-boats constitute a prime part of the security organization. The fleet is now composed of nine vessels armed with pumps giving each of them a minute capacity varying from 6,000 to 12,000 gallons; and the flotilla's united output totals 70,000 gallons a minute, which is about equal to that of 100 second-class engines. The larger boats are able to drive water inland through lines of hose 3,000 feet in length, and therefore are available for battling with flames fairly remote from the water front. In 1919, the entire fire department used in extinguishing blazes 142,033,503 gallons of fresh water and 84,770,217 gallons of salt water. In that year, despite all that was done, the

FIREMAN FITTED WITH OXYGEN HELMET AND HEAD TELEPHONE REPORTING CONDITIONS IN A GAS-FILLED CELLAR

aggregate fire losses totaled $12,488,258—a per capita loss of $2.08. This was the record notwithstanding that 90 per cent of the fires were confined to the point of origin.

With the present-day facilities at their disposal, and the decidedly complex problems confronting them in many directions, the firemen of a modern city would be quite unequal to their tasks if they were expected to qualify only by casual association. Recognizing this the City of New York has instituted a fire college course, and there the men are instructed in every branch of their work. They are taught, besides, how to avoid and where to expect that dreaded phenomenon, the back draft; they are tutored in the chemistry of fire; and they are shown how to contend with blazing oil and other combustibles which may be rendered doubly devastating if water is turned loose upon them.

Finally, the enlightenment of the public goes on continuously, for the people at large, by reason of carelessness, are directly accountable for the vast majority of our destructive fires.

Blasting with Liquid Oxygen

An Explosive Developed by the Germans to Meet the Exigencies of the War

By S. P. Cortland

Photos by courtesy U. S. Bureau of Mines

MINING by means of liquid oxygen as an explosive has obtained a foothold in the United States, and two important operators in this field of industry are using the novel blasting medium in certain non-gaseous coal mines and in sections where copper ore is dug out by the open-cut method. Such is one of the potentially helpful reflexes of the World War.

The Central Powers had not been long in conflict with the Entente Nations before they realized that they would have to husband every pound of the materials essential to the making of military explosives. Nitrates and glycerin were at a premium; and the Teuton cause was doomed to a sudden collapse unless other shattering mediums could be evolved for indispensable mining and for the execution of undertakings of an engineering and kindred character. Such was the situation, but the pressing question was, What could be counted upon as an efficient substitute? After a little pondering the technicists answered, liquid air.

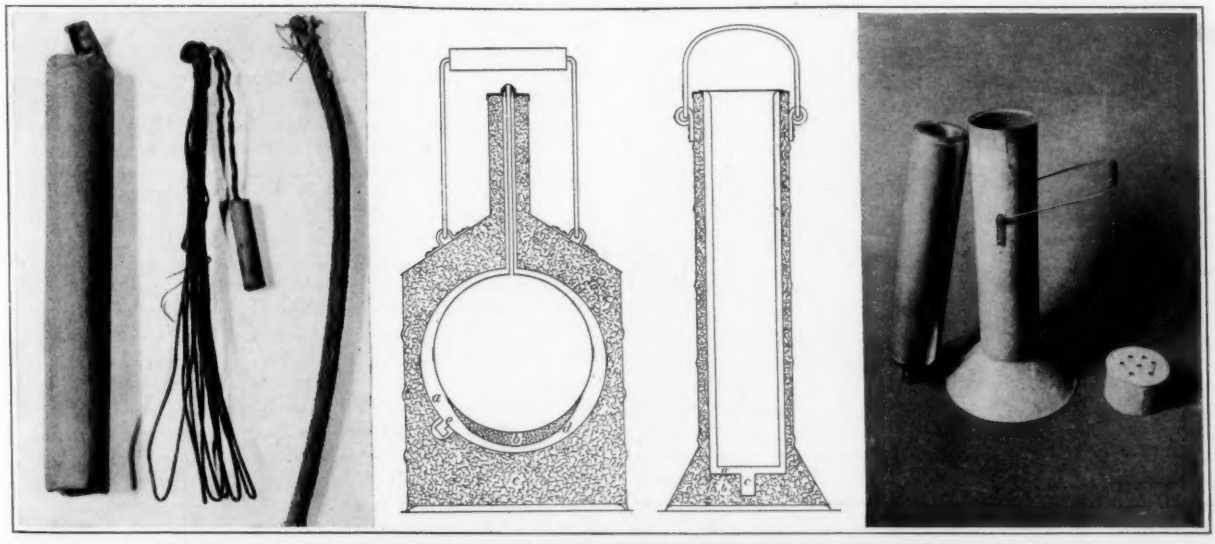
The proposal was not revolutionary, for it entailed nothing more radical than the resumption of developmental work that had been dropped about fifteen years previously. In 1899 liquid air as an explosive then known as "oxyliquit," was tried out during the driving of the famous Simplon Tunnel. Although the demonstrations were declared to be convincing and the results substantially equal to those obtained with like quantities of blasting gelatin, still the use of the patented compound ceased after the death of the engineer who was in charge of the experimental applications.

True, in a desultory way, steps were taken by those commercially interested to perfect the explosive, but the mining fraternity was not responsive, and oxyliquit was looked upon more as a laboratory achievement than as an explosive that could be adopted in every-day practice. When tested during the excavation of the Simplon Tunnel, oxyliquit was a mixture of crude petroleum, soot, and kieselguhr duly saturated with liquid oxygen containing a considerable percentage of nitrogen.

It was the nitrogen factor that did much to impair the reliability of the compound by inducing a lack of uniformity in the explosive action. This is not hard to understand, for the inert character of nitrogen would be apt to slow up ignition and to repress complete and speedy combustion. Twenty-odd years ago, the manufacture of pure liquid oxygen was fraught with many difficulties, and such being then the state of the art there was warrant for skepticism that oxyliquit or any other explosive of that class could ever be expected to compete with dynamite, black blasting powder, etc.

But in 1900 Georges Claude of France brought out an air liquefying apparatus of a markedly superior type; and two years later, Karl von Linde, in Germany, evolved his rectification equipment. From then on the low-temperature fractional distillation of highly-compressed gases moved forward rapidly. Liquid oxygen, liquid hydrogen, and liquid carbonic gases became commercial commonplaces. About 1904 Sir James Dewar invented a way to obtain a high vacuum in a double-walled vessel; and the Dewar flask thus offered a container that could be relied upon to decrease greatly the rate of evaporation of liquefied gases held within it. Despite these various improvements in the art, little attention was devoted to the further practical application of liquid-oxygen explosives until after the fateful 1st of August, 1914.

Soon after the Central Powers laid down their arms in November of 1918, Mr. George S. Rice, of the U. S. Bureau of Mines, went to Europe and made an investigation of the use of liquid oxygen for explosive purposes in Germany, and



CARTRIDGE WITH CARBONACEOUS FILLING AND VESSELS USED FOR SOAKING IT IN LIQUID OXYGEN

The photograph on the left shows the cartridge (9½ inches long), the electric detonator and a piece of the black powder fuse employed by the Germans. The drawing on the left is a sectional view of a liquid air container used by Germans during the war; *a* evacuated space, *b* charcoal, *c* insulating material, *d* screen for holding charcoal in place, *e* attachment for exhausting air. The next drawing shows a vessel for soaking cartridges in liquid oxygen; *a* evacuated space, *b* insulating material, *c* connection for air pump. The photograph on the right shows at the left, a double-walled liquid-oxygen flask; in the center, the carrier lined with felt or other insulating material, while at the right is the perforated cap or cover from which the cartridges can be suspended during soaking.

many of the facts herein related have been furnished by that expert. Further, from other sources, data have become available revealing the extent to which the Germans have adopted the new explosive in various fields of mining since the close of the conflict. All of this information tends to show that liquid oxygen as a blasting or shattering medium has come to stay.

Liquid oxygen alone is not strictly speaking an explosive, but its boiling point is about 298 degrees Fahrenheit below zero. At any temperature from that upward it vaporizes rapidly. If the container be sealed, and the expanding gas be offered no easy channel of escape, the pent-up pressure may become sufficiently great to burst the vessel holding liquid oxygen—the ultimate violence depending upon the external temperature and the strength of the imprisoning walls. But if the flask have a suitable vent, then the frigid fluid is fairly harmless. It is only when the liquid oxygen is combined, through saturation, with a suitable carbonaceous material that it becomes a powerful explosive, and can then be fired either by a fuse or an electric spark. Until the liquid oxygen and the carbon are thus brought together, the ingredients are innocuous. In this respect liquid-oxygen explosives differ fundamentally from dynamite, blasting gelatin, etc., and can be handled with a great deal of freedom in the meantime.

As might be expected, a special technique had to be evolved to deal effectively with an explosive that basally was so unlike the ordinary shattering agencies. At the start there was

LIQUID OXYGEN HANDLING EQUIPMENT USED BY THE GERMANS FOR THE DESTRUCTION OF THE LONGWY STEEL WORKS

some difficulty experienced in manufacturing a satisfactory cartridge, and with this overcome it required some time to learn how to manipulate the charge. Similarly, various carbonaceous substances were tested before the right ones were discovered. Powdered cork, sawdust, soot, ground straw, etc., have been utilized; and during investigations carried out here by the U. S. Bureau of Mines, at the Pittsburgh Experiment Station, carbon in the form of crude oil, lamp black, and wood pulp has been employed. Surely, a rather wide range of choice.

The Bureau of Mines began its researches in March of 1917, and, with the data then available, our technicists sought to find the best way to use the explosive and how to produce it of a strength equal to that of standard dynamite. Different carbonaceous ingredients were mixed with liquid oxygen of varying degrees of purity, and a cartridge of a special pattern was designed. The envelope for the carbon was a small cheesecloth sack averaging an inch in diameter, and was arranged to carry an electric detonator. The cartridge shell was composed of two cylinders of pasteboard—each having one end closed—the smaller sliding inside the larger tube. The investigational work is still under way.

To charge the cartridge, so to speak, the bag, with its carbonaceous filling, is dipped in liquid oxygen for ten or fifteen minutes, and is then withdrawn and placed within the telescoping cylinders. During the soaking period these pasteboard shells are chilled by exposure to the frigid vapor escaping from the liquid-oxygen flask. This vessel, patterned in principle upon the Dewar flask, is a triple-walled affair of metal—the innermost receptacle being successively enveloped by an evacuated space and then by a mass of insulating material. Right beneath the liquid-oxygen container is attached a mass of granular charcoal which is held in place by a perforated metal screen. When this charcoal is chilled by the neighboring liquid oxygen, the refrigeration serves to increase immensely its gas-absorptive capacity; and by reason of this phenomenon the exhaustion of the so-called vacuum chamber is made more nearly complete. In this way the vacuum, primarily induced by pump, is automatically corrected from time to time to take care of impairment. The container is used to transport the liquid oxygen from the point of preparation to the scene of operations, and is provided with a stopper with a small vent through which the "steam," that is continually given off, can reach the atmosphere.

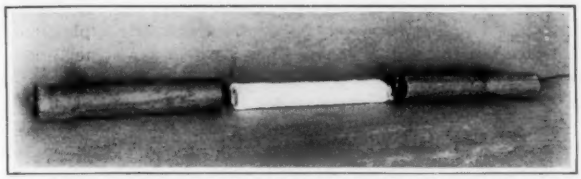
The soaking receptacle, also doubly insulated, is a wide-mouthed contrivance to facilitate the dipping of the cartridges. The liquid oxygen is not poured into it until it is time to get ready for blasting. Inasmuch as the object is to effect the complete combustion of all of the carbonaceous material so that the resultant fumes will be CO_2 rather than poisonous carbon monoxide, it is essential that enough liquid oxygen shall be absorbed by the cartridge to bring this about. Accordingly, in determining the amount of liquid oxygen for this purpose it is essential that the weight of the pasteboard tubes as well as the cheesecloth shall be added to that of the carbon in the bag.

The procedure adopted in loading a hole for blasting by our experts is substantially as follows: When the assembled cartridge, carrying a detonator with the electric circuit projecting, has been duly saturated with liquid oxygen and is frozen stiff, it is shoved into the drill hole and followed by a wad of cotton. Next, a small brass tube is slid into the hole and the rest of the cavity tamped with moist clay. On the withdrawal of the tube a passage is left for the emission of vaporizing oxygen prior to the detonation of the explosive. It is said that this escaping oxygen, if open lights are used, presents practically the only cause likely to lead to premature firing. However, if there is neither coal dust nor fire damp present, this risk is really no greater than when any other high explosive is employed, and the menace is less than when black blasting powder is charged into a drill hole with bare flames near by.

As the reader has probably grasped, liquid-oxygen explosive dissipates its potential violence through evaporation if not detonated within a short time—in practice ten or fifteen minutes after removal from the soaking bath. While this has its drawbacks, and limits the number of holes that can be charged and then fired simultaneously, still there are consequent advantages. Unexploded cartridges of dynamite or black blasting powder are hazardous things to dig out after misfires, and more than once have occasioned unexpected catastrophes when hidden away in the coal or ore coming from a mine. Half an hour after a liquid-oxygen cartridge has failed to detonate it becomes impotent through evaporation.

During a series of comparative tests by the Bureau of Mines with its ballistic pendulum, used for measuring the force of explosions, it was found that the unit strength of the liquid-oxygen explosive prepared by the Government technicists was 4 to 12 per cent greater than that of 40 per cent nitroglycerine; and when tried in a practical way at a stone quarry near Pittsburgh the shattering work done was at least equivalent to that of 40 per cent dynamite. It was also proved that in an atmosphere containing 4 per cent of methane and with coal dust present, both the dust and the gas were ignited. Therefore, the new explosive cannot be used in gaseous coal mines. The firing of the gas and the dust were due to the increased duration of the flame of the liquid-oxygen blasting material; and, furthermore, the actual length of the flame was 2½ times longer than that of the average permissible explosive.

With a comprehension of the limitations peculiar to liquid oxygen in this new field, let us see what Mr. Rice and others, acting for the U. S. Bureau of Mines, learned while abroad. As may be recalled, the Germans systematically destroyed the steel plants at Longwy before retreating, and as a preliminary to this wrecking they installed a Linds liquefying equipment. The cartridges used were of strong paper and were made by wrapping it three times around a split, wedge-shaped wooden former, circular in cross section. The taper being designed



THE CARTRIDGE, THE TELESCOPING PASTEBOARD SHELLS AND THE ELECTRIC DETONATOR WIRES

to facilitate taking off the finished cartridge shell. The outer edge of the paper and the bottom of the container were glued together; and after loading with soot or other carbonaceous material, the surplus paper at the top was merely crushed in or folded down and over. These cartridge cases were 12 inches long and 1.2 inches in diameter. Fuses were provided with detonators having pointed ends; and the carbonaceous material with which they were charged was cork charcoal. The detonators were made ready for service by soaking in liquid oxygen.

At the Aboué iron mine, in the Briey district, the Germans set up apparatus for the manufacture of liquid-oxygen explosives when they took possession of French Lorraine, and as long as they held the territory they employed the new explosive in their mining operations. Again, at the Moyeuvre iron mine, in what was formerly German Lorraine, the Teutons assembled a liquid-oxygen plant, and the French, when they recovered the area, promptly familiarized themselves with the facilities and continued to make successful use of the explosive.

The machinery was started in 1916; was driven by a 300-horsepower motor; and was capable of turning out 75 liters of liquid oxygen hourly. The cartridges adopted for service at that mine were 9 inches long and about 1½ inches in external diameter. They were filled with abraded wood somewhat coarser than ordinary sawdust. The practice was to soak the cartridge for 15 minutes, and the explosive was effective for a quarter of an hour after removal from the dipping vessel. The latter was large enough to hold four cartridges at a time—each of which weighed 100 grams before saturation and 300 grams thereafter. A 5-liter carrying can was the vehicle for transporting the liquid oxygen to the mine, and one of these was sent to each chamber in which worked two miners and one or two loaders. Five liters of liquid oxygen sufficed for making up from 12 to 13 cartridges, and was ample for an 8-hour shift. Indeed, there often remained in the can one or two liters of the liquid oxygen when that vessel was returned to the station for refilling. The rate of evaporation was only 50 grams per hour. Soot was tried as a carbonaceous filling, but it yielded more poisonous gas than the ground wood.

In the Moyeuvre iron mine the ore is dense and strong but shoots easily. Before liquid-oxygen explosive was adopted blasting powder was used. When visited by our representatives, the custom with the French miners was to drill one or two holes, which they then charged and fired. The liquid-oxygen explosive produced such inappreciable amounts of carbon monoxide that the men were able to return immediately to the face after the shot had been fired. The smoke was light and caused no discomfort. At each shot two tons of ore were thrown down. It seems that the new explosive can be made more shattering, like dynamite, by employing finer carbonaceous material. A liter of liquid oxygen cost 1 franc 23 centimes, and with cartridge material and fuse added, the outlay was 1 franc 45 centimes—29 cents pre-war value.

In 1915, according to a German authority, experience disclosed that one kilogram of dynamite would produce 10 metric tons of coal, while a kilogram of liquid-oxygen explosive would bring down 15 tons of coal. That is to say, the dynamite per ton of coal cost 14 pfennig (3½ cents) and the liquid-oxygen explosive for the same service entailed an outlay of 8.3 pfennig (2.1 cents). The same student of the subject has estimated that, even when making liberal allowances for evaporation losses, liquid-oxygen explosives will be less expensive throughout a working year of 300 days than dynamite, which does not dissipate itself or lose its strength in storage.

At Moyeuvre the liquid oxygen was kept in a big reservoir in the liquefying station, and the officials there declared that the stuff would stand with practically no loss of moment during a period of 24 hours. That apparatus represented an expenditure of 30,000 marks which, at the pre-war value, meant an outlay of $7,500. All of the liquefying apparatus in use by the Germans were not of a stationary type. One of the most interesting developments by them has been the construction of small portable outfits having a capacity of from 3 to 5 liters of liquid oxygen per hour. These machines can be moved about on motor trucks, and the engines of the vehicles are readily coupled up with the liquefying installation. This puts liquid-oxygen explosives within convenient reach of various sorts of engineering undertakings. Liquid oxygen was thus employed during the excavating of subways in Berlin; and there is ample warrant for the assumption that mobile liquefying plants played their part in the fields of military operations.

A secret staff document, captured by the British in 1918, contained minute instructions for the Royal Prussian Pioneers covering various applications of liquid-oxygen explosives in the theater of war; and it was specified that the blasting material was admirably suited for the work of cutting communication tunnels and dugouts, for the driving of mine galleries, and for the rapid construction of shelter and other trenches. Indeed, it was officially declared that it was well adapted to the destruction of all classes of obstacles.

Manifestly, if American manufacturers can turn out equally

WITHDRAWING THE CARTRIDGE FROM THE DIPPING VESSEL

satisfactory portable liquid-oxygen apparatus their employment will be advantageous and do away with the transportation and storage of the dangerous explosives now commonly used. It is said that liquid oxygen, when spilled upon the bare skin, will not produce a burn if shaken off promptly. However, the German military authorities caution against wearing gloves when handling liquid oxygen, lest the latter be

absorbed by the gloves and thus held in contact with the skin long enough to occasion injury.

The U. S. Bureau of Mines has recently stated that the Teutons have greatly amplified the service of liquid-oxygen explosives; and, according to statistics issued since the armistice, the Germans have available a total of 136 liquefying plants with a gross capacity of 3,797 liters of liquid oxygen per hour. This possible output no doubt is designed to take care of stand-by and other losses, and probably covers a capacity in excess of actual needs. Even so, assuming that but one-fourth of the potential yield of liquid oxygen is utilized regularly for nine hours daily and three hundred days in a year, this would be equivalent, in the course of a twelvemonth, to quite 5,346,000 pounds of the fluid. Such a quantity of liquid oxygen would produce explosives corresponding in effect to about 8,000,000 pounds of dynamite. At this rate, the substitution of the liquid-oxygen explosive would effect an annual saving of substantially $532,000. The Germans are blasting with the novel material in coal mines, iron mines, and in the mining of salt and potash.

As must be evident, liquid oxygen is the chief cost factor in the preparation of the new explosive—the other ingredients being readily obtainable at very low prices. Therefore, the extensive adoption of liquid oxygen in the field of blasting will depend upon the availability of improved liquefying machines. Work done both in Germany and in France latterly give great promise of the realization of this desideratum, and we can no doubt count confidently upon our engineering concerns profiting by European developments and their own experience in manufacturing compressors, etc.

Despite their advantages, liquid-oxygen explosives have their limitations, but these drawbacks do not overshadow the superiority of the novel explosive in those departments of mining already specified. The lower cost per unit of material blasted is in favor of the liquid-oxygen compound, especially in view of the steadily rising cost of the ordinary standard explosives. And then there is that outstanding virtue of greatly augmented safety—something that is of prime importance.

WHENCE COMES PETROLEUM?

Now that the world actually faces in a not too distant future, the serious diminution, if not the entire disappearance of those vast subterranean lakes of crude oil, the exploitation of which has so marvelously advanced man's comfort in a myriad of ways, the still unsettled question of its origin is more than ever of import to the general public as well as to men of science. There are two leading theories with regard to the formation of petroleum, one of which regards it as of volcanic origin, while the other ascribes it to a resolution of the débris of animals. The question is discussed at some length by M. L. Gentil in *Chimie et Industrie* (Paris) for December, 1920, but we shall here confine ourselves to a brief abstract of the argument for which we are indebted to *Le Génie Civil* (Paris) for February 5, 1921.

The organic hypothesis has been chiefly formulated and supported by certain Roumanian geologists, particularly Professor Mrazec. The hydrocarbons found in nature have two distinct sources: an internal origin, in which case they are found in metallic veins in rock, and an external origin, in which case they are of organic provenience and are found scattered through the strata of the sedimentary rocks. Professor Mrazec terms those strata in which the remains of plankton are found "mother rock" and considers that the hydrocarbons present in these layers are produced by the decomposition of the plankton.

In Roumania, these mother rocks are Tertiary: the most ancient of them which are very rich in foraminifera with some traces of fishes are Paleogenic; the more recent ones form a part of the "Saliferous" strata belonging to the first half of neogenic formations.

The latter strata include the richest mother rocks found in Roumania, but curiously enough, petroleum is not found in these but in the more recent strata of the upper neogenic deposits. This indicates a movement of liquid hydrocarbons through which they have impregnated very permeable territory where strata of sand predominate. This so-called migration of petroleum is oftener upward than downward.

It is only when the sand is super-saturated that the oil can be obtained by driving wells. The roof over beds of petroleum always consists of a rock which is impermeable enough to stop the upward migration of the liquid. In Roumania the best roof is the Pontian, and this explains why most of the exploitable petroleum is found at the Meotian level.

There are various reasons for the migration of the oil, some of which depend upon its composition, as when the gaseous elements contained exert an upward pressure. In other cases the migration is due to various outside causes such as an increase in the expansive force of the gases caused by the temperature of the earth, by the infiltration of water causing the lighter oil to move to its surface, and finally, by orogenic (or mountain-rearing) forces capable of exerting an action from a considerable depth.

An examination of deposits of petroleum yields arguments both favorable and unfavorable to the theory of organic origin. Among the favorable arguments we may mention: the similarity of petroleums to other mineral fuels, the fact that such deposits are generally found not far from gypso-saline strata, their connection with certain tectonic zones exhibiting no eruptive character, etc. Among unfavorable arguments is the fact that increasingly deep borings have succeeded in finding petroleum above strata which had been supposed to belong to the mother rock.

According to M. Launay, the mineral hypothesis is still more untenable. However, it is favored by the ordinary and abundant presence of hydrocarbons in the gaseous discharges from volcanoes, by the existence of carburetted substances in numerous metal-bearing veins and by the mobility and thread-like arrangement which gives layers of petroleum much the aspect of internal mineral veins. The Bucharest authority, Professor Murgoci, believes that Roumanian petroleum must have resulted from the condensation of hydrocarbons which emanated originally from deep lying basic magmas, through fissures, faults, and surfaces of landslides occurring during the formation of the Carpathian Mountain chain. M. Gentil inclines toward the volcanic hypothesis, remarking that the gaseous hydrocarbons present in volcanic eruptions might easily become absorbed and stored up in porous strata of the earth's crust, so as to form eventually deposits of crude oil, supporting his view by the undoubted connection found between large deposits of oil and lines of geologic fracture.

He holds that the great deposits of oil in the Tertiary strata are found around the circumference of the great Secondary and Tertiary geocynclinal, along which have risen the great recent mountain chains like the Alps. And this zone of folds coincides with the volcanic zone which marks the end of the Tertiary era.

Furthermore, the strongest argument of those who hold to the theory of an organic origin, namely, the frequent association of beds of oil and gypso-saline strata, can readily be explained by the volcanic hypothesis, since the distribution of the oil beds of Neogenic eras, lends itself admirably to the theory of volcanic emanations which have traversed geologic strata, along the lines of the great fractures; and since moreover, the movements of sea-coast lines at the time of the formation of the Tertiary chain must have favored the formation of lagoons along the borders of these great Tertiary reliefs.

On the whole, therefore, in spite of the admirable work published in support of the organic hypothesis of the origin of petroleum, M. Gentil is strongly disposed in favor of the mineral theory of its formation.

Testing Explosives Force with the Piezometer*

Pressure-Electricity Produced in Crystals by the Explosive Gases of Guns and Motors

AMONG the most beautiful and interesting objects found in nature are crystals of various kinds, some of them including, of course, very rare and beautiful gems. Crystals, moreover, are peculiarly interesting to men of science, because of their very remarkable characteristic properties. Many of them, for example, have the faculty of polarizing the rays of light which fall upon them and this phenomenon has long excited special attention among physicists. Most interesting of all, perhaps, are crystals of tourmaline and of quartz, which are not only utilized for special purposes in laboratories of physics but have certain valuable industrial applications.

Tourmaline consists, from a chemical point of view, of certain fluoriferous boro-silicates united with alumina in which other minerals are found, particularly magnesia and iron and including manganese, lime, potash and soda with lithine at times, and even traces of phosphoric acid in many cases.

Regarded from its physical aspect tourmaline exhibits rhombo-hedric prisms having from six to nine plane surfaces, but often posssesing a triangular section which recalls a spherical triangle. The color is various, for which reason it furnishes many particularly beautiful jewels to the world of trade; these different colors depend, of course, upon the nature and percentage of the mineral constituents and include numerous shades ranging through black, dark and light brown, green, blue, red, pink, "dregs of wine"; sometimes, too, a single specimen shows several colors.

It is found in various parts of the world—in Siberia and in Brazil, in Sweden and in Greenland, in the Hartz Mountains and within the bowels of Mount St. Gothard, in Cornwall and in Massachusetts, and even in "Elba's Isel." It occurs in granite, in gneiss, in syenite, in chlorotic schists or talc schists, in dolomite, in crystalline lime stones, etc. Quartz is likewise a rhombo-hedric crystal. It is a crystal of silica and is found in very numerous varieties having distinct forms and colors according to the nature and amounts of the foreign matters incorporated with the crystal. It, likewise, is of very widespread occurrence.

Both tourmaline and quartz have a common crystallographic characteristic, namely, that of being hemi-hedric. In other words, they escape that law of symmetry which controls the majority of crystals; thus crystals of tourmaline commonly appear to be prismatic columns terminating at the top and at the bottom by systems of faces which are non-symmetrical; to this fact is due their peculiar behavior with respect to rays of light.

Hemi-hedric crystals—or at any rate those among them which have inclined faces—differ from ordinary or holo-hedric crystals in the possession of the very curious potentiality known as pyro-electricity.

Pyro-electricity.—This property was first observed in tourmaline more than 300 years ago; in 1703 a Dutch observer had occasion to heat crystals of tourmaline for some purpose or another upon a brazier. While they were cooling he was surprised to observe that they exhibited a power of attracting light particles of various sorts. This observation was published in a treatise which appeared in Germany in 1707 and thereafter tourmaline became known as the electric stone or the Ceylon magnet.

Recent authorities have come to think it probable, however, that this property was known even to the ancients. Pliny, for example, has an allusion to "certain minerals which attract light bodies when they are subjected to solar rays or to friction." And it is supposed by Poggendorff that these minerals termed *carbunculus* by Pliny were really fragments of tourmaline.

However, the electrification of tourmaline by heat is an entirely different phenomenon from that exhibited in electrification by friction—in the latter one of the two bodies rubbed against each other is electrified positively and the other one negatively, whereas when tourmaline is electrified it is charged with both kinds of electricity at one and the same time.

By the process of heating there takes place in the case of the tourmaline a dissociation of the two kinds of electricity in the same body, and there is produced between the extremities of the latter a difference of potential, or, in other words, an electro-motive force just as in the case of an electric or thermo-electric battery, although in the former case a homogeneous system is concerned instead of a group of different substances.

This phenomenon can be exhibited in a very simple manner by heating tourmaline crystals in any sort of stove or furnace removing them and sifting upon them, while still hot, a mixture of fine powder composed of minium and sulphur through a muslin sieve. It is this mixture of red lead and sulphur which is employed in the well-known experiment by which the so-called Lichtenberg figures are produced. It is known to scientists that the two powders become electrified through friction against each other, the former positively and the latter negatively; when they are allowed to fall upon the crystals of tourmaline the sulphur is found adhering to one end of the crystal which indicates, of course, that the latter is positively electrified, while the minium clings to the other end of the crystal, showing this to be negatively electrified.

At a later date a closer study of this pyro-electricity brought out the fact that the electrification in question is closely connected with certain elongations and contractions to which crystals are subject. In 1885 Professor Cuire discovered that these phenomena are subject to the great *law of reversibility*, in such a manner that electrification is excited by tension and compression; thus tension exerted upon a crystal of tourmaline in any given direction produces the same effect as heating it, while pressure upon the other hand exerted upon the crystal corresponds in results to cooling it. This law holds good with quartz also.

The phenomenon of piezo-electricity or pressure electricity can also be very simply demonstrated by taking a crystal of tourmaline, as large as possible, and splitting a lamalla from it by a cleavage perpendicular to the principle axis, *i.e.*, the axis running from the base to the summit; upon this sheet of tourmaline there is then placed a sheet of brass connected with an electrometer, while upon the brass there is then placed a weight. When this weight is pressed downward by the hand the electrometer is seen to deviate in a certain direction, while if the sheet of tourmaline be reversed the deviation of the electrometer changes its direction, thus indicating that there has been an inversion of the polarity.

This experiment can be performed in the same manner with quartz instead of tourmaline, but whereas in the case of the latter the piezo-electricity is exhibited only when the pressure exerted is perpendicular to the faces, it is exhibited in quartz also through pressures exerted upon the sides. Professor Cuire proved through his study of the laws of this phenomenon that the *quantity of electricity produced is directly proportionate to the pressure.*

Since Cuire's researches a number of physicists have devoted extensive study to the problems here involved. Boigt has indeed, devoted an entire book to them. It has been established that the crystals in question possess definite electrical axes, along which the pressure applied must be exerted in order

*Translated for the *Scientific American Monthly* from *La Nature* (Paris), for Jan. 8, 1921.

to produce the maximum effect. The latter is produced upon the faces normal to the electrical axes along which the pressure is exerted; upon these faces there can be collected quantities of electricity equal in amount and of contrary size.

The quantities of electricity obtained, q, are proportional to the surface S upon which the electricity is collected, to the pressure P exerted per unit of surface, and to a coefficient x K, which is termed *the piezo electric constant*. These facts can be expressed in the equation $q = KPS$; if q be expressed in CGS units, P in grams per square centimeter, S in square centimeters, then the piezo-electric constant of quartz is $K = 6.45 \times 10^{-8}$ while that of tourmaline will be $K = 5.71 \times 10^{-8}$. (These figures are taken from the list of *Physical Constants*, published by the French Society of Physics.

As we see from the above figures the quantities of electricity thus produced are extremely minute and in spite of the great scientific interest of the phenomenon it was not supposed to be capable of any sort of practical application. Such an application, however, has recently been proposed by the well-known physicist, J. J. Thomson, for the purpose of measuring the degree of pressure produced by explosive forces in fire arms and in explosion motors.

In these engines the pressures are developed in extremely brief intervals of time so that it is very difficult to measure them by means of ordinary mechanical processes. This can be done, however, very beautifully through the phenomenon described above of pressure electricity in tourmaline or quartz, through the device invented by Thomson.

Upon each of the two opposite faces of a sheet of tourmaline a leaf of brass foil is placed; these two leaves are connected with two metallic plates mounted in a vacuum tube; the crystal between these two sheets or leaves of metal is then placed within the medium whose variations of pressure it is desired to examine. Under the effect of the exposure the crystal becomes electrified and produces a difference of po tential between the electrodes of the tube.

The problem now is to observe this difference of potential; for this purpose there is sent between the plates of the tube a flux of electrons produced by a metal filament, heated electrically and placed in a compartment of the vacuum tube which communicates by means of a very narrow channel with the principal chamber within which the two electrodes are placed; at the end of the tube, opposite the filament, there is placed a photographic plate or a screen.

So long as the tourmaline is subjected to no pressure the difference of potential between the plates of the tube is nil, and since the flux of electrons remains rectilinear it strikes the screen in the center; but as soon as any pressure is produced the tourmaline is electrified and a difference of potential takes place between the plates thus causing a deviation in the flux of electrons.

The object of this is to interpret the images thrown on the sensitive plate or screen and for this purpose to prevent them from being superposed; it is not possible to displace the plate within the tube; the solution indicated by Thomson consists in imparting to the flux of electrons itself a definite movement by subjecting the said flux to the action of an alternating magnetic field.

This ingenious idea has already produced interesting results from the observation of the photographs thus made by Mr. Thomson, who expressed the hope, in an address delivered a few months ago, that the device might prove to be of use in various directions. Mr. Thomson also suggested that it may be possible to substitute quartz for tourmaline in such experiments, or even crystals of cane sugar. It may likewise be possible to substitute much simpler and easier methods of observation, such for example as those employed in the case of the tubes emitting electrons which are now in use in the fields of wireless telegraphy and telephony.

An even more interesting realm of experiment in this connection, however, has been recently opened up by the American physicist, A. McLean Nicolson, in his researches on the pyro-electric and piezo-electric properties of other classes of crys tals. This investigator has made a special study of crystals of potassium tartrate and sodium tartrate, which have the advantage over quartz and tourmaline of being easily prepared in the laboratory and of attaining dimensions of considerable size.

Sodico-potassic tartrate is well known in commerce under the head of Rochelle salts, or Seignette salts, the latter term being due to its discovery in 1672 by a pharmacist, Pierre Seignette, living at La Rochelle. Its chemical formula is

$$C_4H_4O_6NaK + 4H_2O$$

It is obtained by saturating potassium bi-tartrate with potassium carbonate; 12 parts of water are brought to the boiling point and 4 parts of cream of tartar and 3 parts of crystallized carbonate of soda are added; the solution is filtered, evaporated and allowed to cool, the handsome crystals obtained being purified by recrystalization.

ELECTRIC STEEL INDUSTRY

THE net increase in the number of electric furnaces in the United States last year has been 33 as against 36 in 1919; 54 in 1918; 97 in 1917; and 63 in 1916. The total is now 356 as against 323 on January 1, 1920. The expansion of the industry is appreciated when it is recalled that there were only 19 furnaces of all types in the United States on July 1, 1913. In Canada the industry is virtually at a standstill. As heretofore the Heroult furnace maintains its leadership in installations and output. Most conspicuous in the progress of the American steel industry last year were the Greene and Greaves-Etchells types. Expansion in the installation of other types have either been small or nothing. A new furnace of small size but of decided interest and practical use is the Von Schlegel repelling arc furnace sold by the Industrial Electric Furnace Company, Chicago. This furnace was described in *Iron Age* for Dec. 9, 1920. Only one of them is operating in the steel industry, but about six are in use in the non ferrous industry. Data regarding the Moore electric furnace and one known as the Volta were not obtainable, except from current news sources. The Volta furnace sold by the Volta Mfg. Co., Welland, Ontario, is an outgrowth of the war. It is the furnace which was developed by Robert Turnbull, now general superintendent of the United States Ferro Alloy Corporation, Niagara Falls, N. Y. It is understood that the United States has been invaded by this furnace and that two are being installed near Pittsburgh.

The world's steel industry as a whole is credited with 961 furnaces of which the United States and Canada are credited with 399 or over 40 per cent. The number of furnaces in the other leading countries are as follows: England, 150; Germany, 100; France, 69; Italy, 50; Sweden, 50; and Norway, 20. The gradual and healthy expansion in this industry in 1920 is an assurance that the United States will continue to hold the supremacy over Germany and all other countries which it wrested in 1916 and which it has held since—both in number of furnaces and in production.

EARTH-CURRENT TELEGRAPHY

A SYSTEM of earth-current telegraphy was somewhat extensively used by the Allied Armies during the war.

At the transmitting station, an insulated wire, some 50 to 70 yards in length, is laid along a trench and carefully earthed at its ends. Intermittent currents are passed along this wire, and corresponding but very feeble currents are picked up between the similar earth connections of the receiving apparatus. A vibrator of particularly substantial construction, giving audible frequencies, is used in series with a Morse key, and the currents are picked up by a telephone in the receiving apparatus, after having been amplified by one or more thermionic amplifiers. With a current of 0.5 ampere and a three-stage amplification the working range is 1½ to 2 miles, and in exceptional cases, nearly 7 miles.—*L'Industrie Electrique*, Jan. 10, 1921. Abstracted by *The Technical Review*.

A New Physical Phenomenon*

Utilizing the Electrical Attraction Between a Conductor and a Semi-Conductor

The following is an abstract of an exceedingly interesting paper which was read at the City Hall of Copenhagen last August before a distinguished audience of scientists at the celebration of the 100th Anniversary of the birth of H. C. Oersted, the Danish scientist who discovered Electromagnetism. The paper describes a new discovery, capable of a number of applications which the inventors demonstrated by means of experiments.—EDITOR.

TWO Danish engineers, Mr. A. Johnsen and Mr. K. Rahbek, have been occupied during the past two years with the endeavor to discover a practical application for a new physical phenomenon recently discovered by them, which may be stated as follows:

When a sheet of gold leaf is attached to one side of a lithographic stone and a sheet of brass is placed against the opposite smooth side of the stone, and the gold leaf and the sheet of brass are connected with a direct current of 220 or 440 volts, the brass will cling tightly and with great force to the stone. When the current is interrupted, the stone and the brass will fall apart. This phenomenon is to be explained in the following manner:

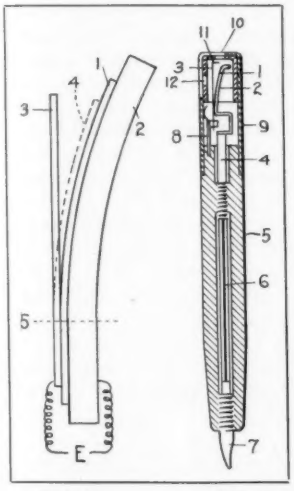


FIG. 1

FIG. 2

The potential between the gold leaf and the sheet of brass is distributed through the semi-conductor, the stone, with a comparatively insignificant drop, so that the potential on either side of the very small air space separating the stone and the brass becomes great, disclosing the existence of great forces.

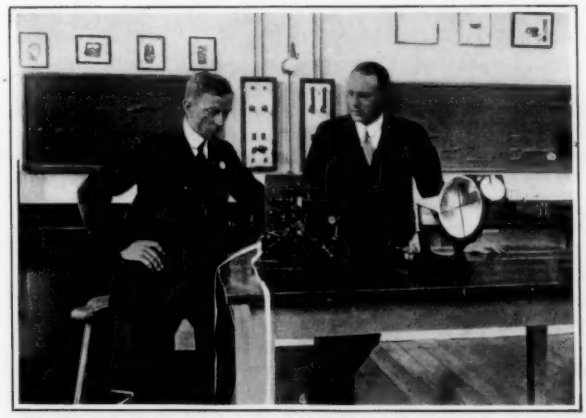
In order to make use of this phenomenon for technical purposes, the two inventors have employed the well known principle applied in brakes where a band slides on a rotating drum. For this purpose a gelatin band is used with one end attached to a telephone diaphragm and passed over a rotating metal drum to a spiral spring so arranged as to hold the band tight against the face of the drum. When a current of electricity passes from the spiral spring through the semi-conductor (which is in this case the strip of gelatin) to the rotating drum, the variations in the current will produce a greater or less degree of adhesion of the gelatin strip, and the greater or less degree of friction thus occasioned will have the effect of producing a corresponding variation of pull on the telephone diaphragm.

In order to make use of this discovery in a loud speaking telephone, the latter is connected in series with a battery in the secondary of a transformer, so that there will be produced a direct current of varying strength. Instead of a telephone diaphragm, the sounding board of a violin can be employed for the reproduction of music. The phenomenon has also been applied to the recording of wireless waves which are amplified by an audion and also rectified by the same to a direct current of varying strength. Upon the principle just described is based a recording apparatus which registers the variations in the current upon a strip of paper. In this instrument a rotating agate drum is used, and on the circumference is a metal band under the influence of the variations in the current. A stylus records the movements of the band on the strip of paper, forming a wave line, comparable to telegraphic symbols. By means of this apparatus it is possible accurately to transcribe wireless telegrams at a speed of 300 words per minute.

An electroscope has been constructed which works upon the same principle and is intended to detect faulty lamp sockets, switches or other parts of electrical installations. Examinations can be made by means of this apparatus without test wiring or special preparations. This apparatus will undoubtedly, like the fountain pen, meet a long-felt want, on account of its being highly sensitive and the ease of carrying it in a pocket.

Fig. 1 shows the principle of the apparatus. Here *1* is the semi-conductor, which in this case consists of gelatin spread in a uniform layer over and in intimate contact with the slightly curved conducting sheet of metal, *2*. One pole of the current is connected to the metal, while the other pole is connected to an elastic, slightly curved, conducting strip of aluminum foil, *3*, whose lower end is steadily pressed against the semi-conductor *1*, so that the flat surfaces of the foil *3* and the semi-conductor *1* (which face each other) will come in contact with each other on a tangent approximately along the line *5*.

If the potential between the sheet of metal *2* and the metal foil *3* is of suitable amount that part of the foil *3*, adjacent to section *5* where the air space is inappreciable, will be attracted with great force toward the gelatin covering of the sheet metal. The force is so great that it will overcome the elastic resistance against bending. As the foil gradually bends toward the gelatin layer, the source of power moves upward with the result that the entire metal foil *3* is placed, by a rolling motion, snugly against the gelatin layer in position *4* as indicated by dotted lines in Fig. 1. The fact that the uppermost end of the foil *3* has the greatest amount of



MESSRS. JOHNSEN AND RAHBEK DEMONSTRATING THEIR AMPLIFYING APPARATUS WITH WHICH RADIO SIGNALS ARE RECORDED ON A PAPER TAPE

motions is utilized in the practical application of the apparatus for indicating a difference of potential.

If the connection with the source of the current is broken, the foil will linger in the position *4* shown in Fig. 1 and will not come back to the original position *3* until the potential by the gradual discharge through the semi-conductor has decreased to such an extent that the elasticity of the foil *3* is able to overcome the force of attraction. The semi-conductor may be so chosen in respect to conductivity as to cause the

*Translated for the *Scientific American Monthly* from the *Elektroteknisk Tidsskrift* (Copenhagen) for October 20 and December 20, 1920, Nos. 30 and 36.

discharge to vary from a fraction of a second to several minutes. If the current between the sheet of metal *2* and the foil *3* be short circuited, the conducting foil will at once straighten out.

Fig. 2 shows in cross section a practical application of this apparatus. In this figure the metal sheet *2* is bent in the manner indicated and is covered on the left hand side by a layer of gelatin *1*. The metal sheet is fastened to the metal upright *4* which is screwed to the ebonite tube *5*. The metal sheet is connected through the metal upright and through a graphite resistance *6* of ½ megohm with the metal point 7, which projects from the jacket *5*. The curved foil *3* is conductively connected to the upper metallic part of the jacket *9* by means of the curved contact spring *8*. Now when one wishes to ascertain if a certain potential exists between a conductor and the ground, the upper part *9* of the jacket is held in the hand and the metal point 7 is brought in contact with the conductor or the particular part of the installation in question. If there is a current in the conductor, the metal foil *3* will roll over as shown in Fig. 1, and the red mark *11* painted on the metal foil *3* will come to a position in front of the window *10*. The apparatus is so sensitive that it does not matter whether the person making use of it has a good connection with the ground or not; he may for instance be standing upon a wooden ladder. In certain circumstances where the red mark cannot conveniently be observed and when the electroscope has a perceptable period of discharge, the motion of the metal foil can also be observed through the window *12*.

As a result of the fact that the resistance *6* is very great, the operator runs no risk of receiving an electric shock in case of a short circuit through the substance of the gelatin.

The metal foil can be made heavy enough for the apparatus to bear transportation and to bear handling in any position, because strong electric forces are active in the apparatus. On the other hand its sensitiveness is so great as to indicate reliably a potential of 220 volts.

The apparatus can be used quite as well for an alternating current, as for a direct current.

THE ELECTRICAL EXPRESSION OF HUMAN EMOTION

IN a discourse delivered on February 4th, before the Royal Institution, Dr. A. D. Waller, F.R.S., director of the Physiological Laboratory, University of London, dealt with the invisible and insensible manifestations of emotion which accompany visible responses such as muscular movements and secretory discharges. Dr. Waller at once proceeded to demonstrate the phenomena which he has been investigating during recent years and which were first described as psycho-galvanic reflex phenomena, by Veraguth (Berlin) in 1909. Dr. Waller's first subject was a "normal person," a medical man. Electrodes (zinc disks covered with chamois leather impregnated with salt solution) were strapped to his hand and coupled in series with a battery of a few cells and a galvanometer, so as to form one arm of a Wheatstone bridge. Another pair of electrodes in circuit with another galvanometer was attached to the forearm. The two light spots were marked *H* and *A* respectively. Bridge balance having been established, Dr. Waller threatened to prick the subject with a pin; *H* was deflected, marking a decrease in resistance, and was again deflected, but rather less strongly, when the pin was really applied after a while. The *A* galvanometer took part in these movements, but the deflection was merely a slow creeping movement. Similar observations were made when the lecturer lighted a match to burn the subject, and when he spoke of blowing a motor horn. The suggestion of the pain or noise had a more marked effect than the actual application of the test. The response was thus not under our control—though this statement had to be qualified—and that made these tests valuable for discovering cases of malingering.

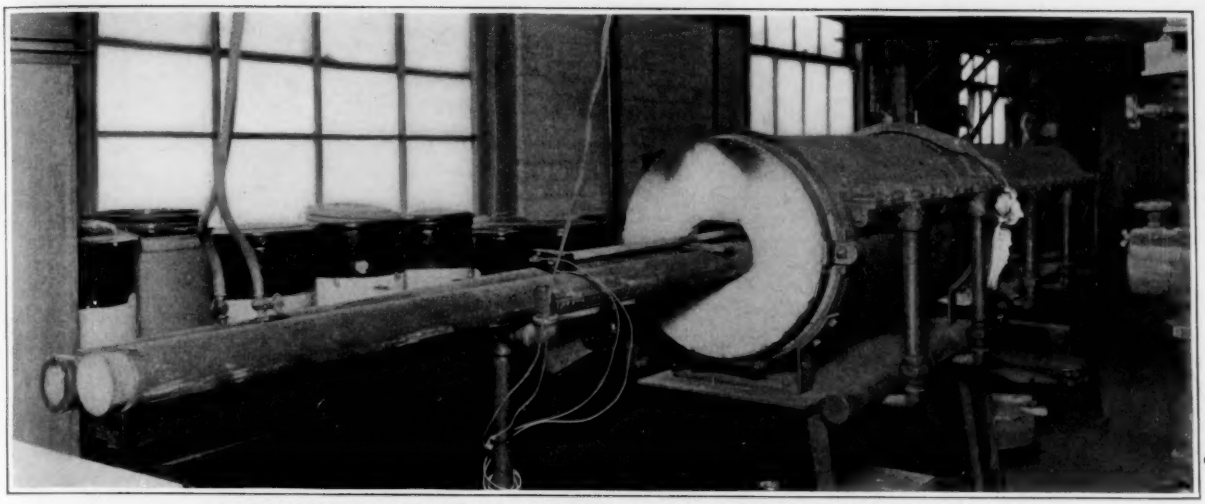
Dr. Waller showed, however, that people are not all equally sensitive in these respects. The four spiritualistic mediums whom Dr. Waller had been able to examine had proved remarkably sensitive; in their case both the *H* and *A* would respond almost equally and at the same moment. Dr. Waller exemplified this at a later stage with another subject whom he would class with the highly sensitive or imaginative people. Most men and women were normal and gave the palmar response H, but hardly any forearm *A* response; in them the response to fiction was greater than the response to the fact. He had also found insensitive people giving neither response, among psychiatric and shell-shock cases. Dr. Waller remarked that he thought he could distinguish a true medium from a false medium by his tests.

Confirmatory evidence was adduced by a great many photographic slides which also showed by their time scale, what the demonstrations had made quite striking, that the electric response is not instantaneous with the emotion, but follows it after a distinct lag or one, two or more seconds. The slides further gave the myograph, the curve of muscular activity. When the subject had raised the finger, the muscular contraction was at once recorded by an increase in electric resistance, while the emotional decrease in resistance lagged behind.

In general the hand or palmar response was more rapid than that of the foot, and the foot more responsive than the leg, but the latter did not hold for very sensitive people. Most of the curves were very jagged, the galvanometer coming to rest after rapid oscillations. As the measurements were resistance determinations, and as the palm of the hand proved the most responsive part of the body, Dr. Waller had taken continuous observations of his palmar resistance. He then observed fairly regular diurnal variations of the resistance, the resistance being greater at night than during the active hours of the day, and that variation seemed to run parallel with the emotional activity. In order to decide whether the diminution of the resistance following and marking emotion was a real decrease of resistance or due to some electro-motive force (a diminution of the e.m.f. of polarization) he also placed a potentiometer in series with the bridge arm. These experiments showed that there was a real diminution of the resistance.

Dr. Waller hence came to the conclusion, a few years ago, that the emotional response depended upon the dilatation of the membranes through which the ions pass in general vital activity. When the nerve impulse reached the membrane, the protoplasm contracted, and the pores became dilated (somewhat as the pupil dilated), so that more ions could pass and more carriers of the current entered into action. By watching a galvanometer in the palmar circuit one could see oneself live, in a sense. During the active hours of the day the pores were more dilated; at night, and when we were fatigued, the pores contracted. Any discharge in the nerve system, whether emotional or not, thus gave rise to galvanic phenomena. That was in accord with the palmar resistance measurements mentioned and with other observations. The response of the right hand was more intense than that of the left hand, but the curves were parallel. Hand and foot mostly went parallel as well, but when the hand response lagged two seconds behind the emotion, the foot response might lag by four seconds. The dilatation of the pores itself was not instantaneous, requiring about two seconds to become effective. Various observations made during the air-raids of the war brought out some curious facts. In one case the maroon signal and the anti-aircraft guns had not produced any effect, but the hum of the Gotha was marked by a strong deflection, corresponding to a resistance-decrease of about 4,000 ohms, much greater than in the laboratory experiments. A certain control seemed therefore possible.

We should add that Dr. Waller offered his explanation of the phenomena as merely a working hypothesis, not yet as a theory.—From *The Electrician* (London), February 11, 1921, p. 202.



HYDROGEN FURNACE FOR THE REDUCTION OF TUNGSTEN AND MOLYBDENUM

Industrial Applications of Hydrogen

The Many and Widely Varying Uses to Which This Gas Is Being Commercially Put

By Harry L. Barnitz, Ph.G.

THE industrial application of hydrogen generally speaking has only been brought about in the last decade. New processes wherein hydrogen will be required in large or moderate quantities are continuously and rapidly being developed, due to extensive research at the present time conducted in the laboratories throughout the world. No element today is receiving more study than the industrial production and application of hydrogen, and it is anticipated that many remarkable discoveries for its industrial use will be announced.

In the hydrogenation of oils, hydrogen has found its greatest applicability up to the present time and this development will employ even greater quantities than heretofore, as the industry is as yet in its infancy. In the immediate future hydrogen no doubt will find its greatest application in the production of synthetic ammonia, liquid motor fuel and further extended uses in metallurgy.

The commercial applications of hydrogen in the processes to be described are those which were developed practically during the last decade and up to the present time and are impressive as to its possible, enormously extended, industrial use in the future.

THE SYNTHETIC PRODUCTION OF AMMONIA

The discovery of the synthetic production of ammonia by Professor Haber[1] of Karlsruhe a few years ago promises a very extensive use for hydrogen. It is of immense importance inasmuch as it forms the basis of the well-known fertilizer, sulphate of ammonia. When hydrogen and nitrogen are heated at 600° to 700° C., in their combining proportions, under a pressure of about 20 atmospheres and in the presence of uranium as a contact substance they unite to form ammonia; about 6 per cent of ammonia is produced and by removing this a further conversion is effected. Very recently the yield has undoubtedly been greatly increased and the process accelerated by the selection of a possibly more suitable contact substance and the application of possibly more appropriate temperature and pressure.

[1]This process was used on a large scale by Germany during the war in connection with the manufacture of explosives.

Nitrogen and hydrogen directly unite to form ammonia under proper conditions as indicated by the equation:

$N_2 + 3H_2 \rightleftarrows 2NH_3$

1 vol. 3 vol. 2 vol.

Heat evolved as indicated by the equation:

$N + 3H = NH_3$ (gas) $\div$ 11,900 calories = 727,000 B.t.u. per sq. ton S./A

The above equation is reversible, depending upon the equilibrium represented by the expression:

$$K = \frac{P_{NH_3}}{P_{N_2}^{1/2} P_{H_2}^{3/2}}$$

where P_{NH_3}, P_{N_2}, P_{H_2} represent the partial pressures of the respective gases NH_3, N_2, H_2 and K is the reaction constant. As noted, 4 volumes of the mixture of nitrogen and hydrogen produce two volumes of ammonia and therefore, as in the case of all gaseous reactions where the products of interaction occupy a smaller volume than the original components, an increase of pressure favors the formation of the products possessing the least volume. Works for the production of synthetic ammonia by this process on a large scale have been erected at Oppa, near Ludwigshafen by the Badische Aniline und Soda Fabrik. No information as to details of the method have been made public of the process as worked in a commercial plant. However, details of Haber and Le Rossignol's experimental plant have been published. Fig. 1 is a sketch of Haber and Le Rossignol's experimental apparatus.

Passing through the tube *F* a mixture of 1 vol. nitrogen and 3 vols. of hydrogen under a pressure of 200 atmospheres enters the strong steed vessel *MM*. After passing over the outer surface of a number of capillary metallic tubes *W* which serve as a heat interchanger and regenerator which is explained later—the gas passes through the tube as shown, over the surface of an electrical heating coil *AA*, where the temperature of the gas is increased to 800°-1,000° C., then back up an interior iron tube *S*, over the layer of catalytic substance *B*, thence through a number of capillary tubes *W*, out through the tube *X*, thence through the compressing pump *P*, working

at 200 atmospheres pressure, thence out through the tube *E*, through the set of capillary tubes *X*, and so into the vessel *H*, which is surrounded by a freezing mixture of solid CO_2 and ether at a temperature of 60° or 70°, which causes the ammonia in the gas to separate in the liquid state whence it can be drawn off by the cock *J*. From *H* the gases pass away by the tube *F* over the exterior surface of the system of capillary tubes *X*, thence after passing over a soda-lime drier *K*, the gas enters *M* as previously described.

The cold gas entering *MM* by the pipe *F* is heated by passing over the bundle of capillary tubes *W* conveying the hot gas away from the contact substance *B*. Thus the entering gas is, by the time it has left *W*, preheated to a temperature of 400° to 500° C., and in so doing has abstracted practically all the excess heat from the hot gas passing away from *B*, so that this latter, by the time it reaches the pipe *X*, is practically at atmospheric temperature, while at the same time the entering gas, by the time it reaches the heating coil *A*, is already at a high temperature, so that practically no loss of heat occurs. For this reason *W* is called the "heat regenerator." The hot gas thus entering the tube *SS* is further heated in its passage by the electrical heating coils surrounding the end of the tube *SS* to a temperature of 800° to 1,000° C. The hot gas then passes into the contact substance *B*, which is maintained by the hot gas at a temperature of 500° to 700° C. Here the formation of ammonia takes place, 3 to 7 per cent of the entering nitrogen and hydrogen escaping as NH_3 along with the excess of uncombined nitrogen and hydrogen. The hot mixture of gases from *B* then streams through the series of fine capillary tubes *W*, and in so doing gives up practically all its heat to the cold entering stream of gas coming into the apparatus at *F*. The gaseous mixture, now cooled to ordinary temperatures, passes away through the pipe *X*, into the pumps *P*, working at 200 atmospheres, and then passes through the series of capillary tubes *X*. While passing through there it meets with a cold stream of gas at 60° C. coming from the vessel *H*. Consequently, the gas in the capillary tubes *XX* parts with its heat *L*, the cold gas coming from *H* being itself chilled in so doing, and passes out of *X* through the pipe *DD* into *H* at a temperature only slightly above that of the cold gas escaping from *H*. The cold gas passing from *H* up *F* is heated almost up to atmospheric temperature by the capillary tubes *X*, and thus passes away through the drier *K* and enters *MM* at *F* at a temperature only slightly below atmospheric. For this reason the tubes *X* are called the "cold regenerator."

The gas entering *H* contained 3 to 7 per cent of NH_3, and this condenses in a liquid form at the low temperature (— 60° C. to 70° C.) prevailing therein, owing to the surrounding freezing mixture of solid CO_2 and ether. This ammonia can be drawn off in a liquid form by the tap *J*, or, if required in a gaseous form, can be so obtained by opening the outlet valve to a suitable extent.

As the ammonia is withdrawn a fresh supply of nitrogen-hydrogen is added through the valve *O*, so that the operation is a continuous one.

PRODUCTION OF ALCOHOL

Alcohol is now being produced for industrial purposes from calcium carbide through treatment with hydrogen. No detailed working description has been announced, but a general outline of the process has been published recently which is as follows:

"Acetylene is passed through acidulated water containing a mercury salt, whereby acetaldehyde is formed; the latter is vaporized, mixed with hydrogen and the mixture passed over a nickel catalyst, when alcohol results. Alternatively acetaldehyde is converted into acetic acid by passing the vapor, mixed with oxygen, over a nickel catalyst. It is stated that a plant is being built near Visp in Wallis, Switzerland, capable of an annual production of 100,000,000 kg. alcohol by this process, this being sufficient to cover the whole requirement of Switzerland."

PURIFYING OILY MATERIALS

Deodorizing fatty oils by treatment of hydrogen has been known for some time by those operating the hydrogenating process, in which identical results are obtained in the presence of a catalyzer. Hydrogen treatment in the process of purifying fatty oils is one which is accomplished in the absence of a catalyzer and does not affect its physical character—in other words it remains liquid whereas in the presence of a catalyzer the oil becomes hard.

It is claimed that deodorizing oils by hydrogen is superior to the steam deodorizing process for certain vegetable and fish oils and that their keeping qualities remain sweet for a longer period.

The method of deodorizing any oil or fat by this process consists of blowing hydrogen, or a gas whose principle constituent is hydrogen, through the heated oil and allowing the hydrogen with the entrained vapors from the oil to escape freely from the containing vessel until the desired result is obtained. In the commercial application of this process, the

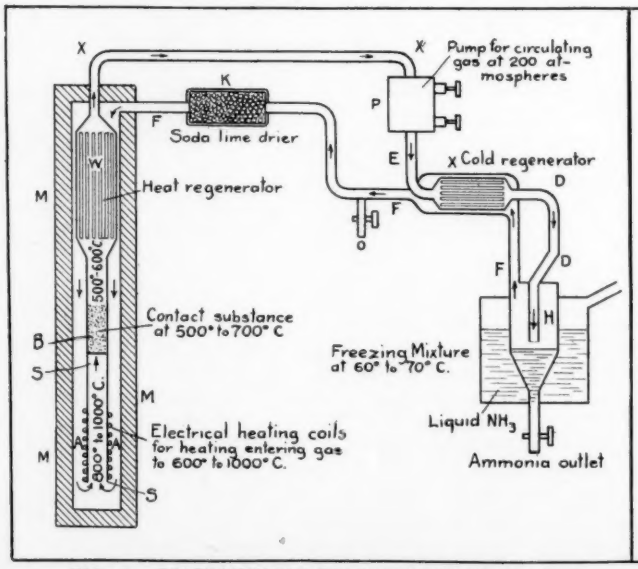


FIG. 1. DIAGRAMMATIC REPRESENTATION OF THE HABER AND LE ROSSIGNOL PROCESS FOR SYNTHETIC AMMONIA

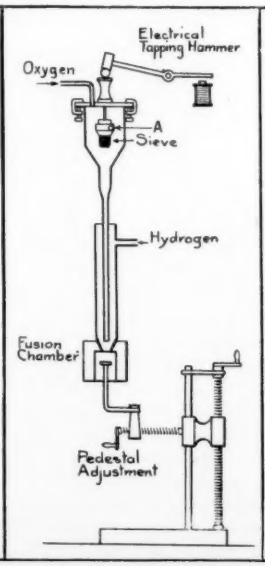


FIG. 2. VERNEUIL'S FURNACE FOR SYNTHETIC JEWELS

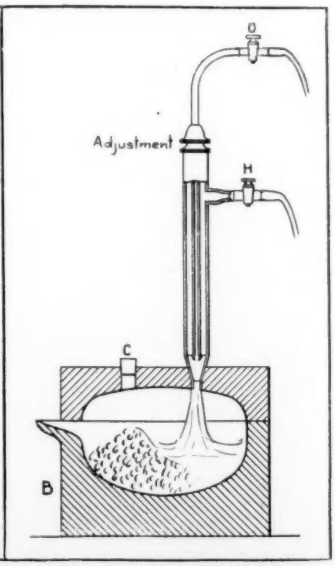


FIG. 3. OXY-HYDROGEN FURNACE FOR MELTING PLATINUM

USING THE OXY-HYDROGEN FLAME FOR MELTING AND FORMING ARTICLES OF FUSED SILICA

fatty acids and other fumes are condensed and washed from the hydrogen, which is thus completely purified and used over again. The entire apparatus should, of course, be filled with hydrogen to the exclusion of all oxygen from the air at the time of its first use. Thereafter, each new batch of oil is introduced and the deodorized oil withdrawn through pipes so that no air enters the apparatus. A means of drying the hydrogen is provided in the gas-purifying system if the oil being treated contains appreciable quantities of water.

The means whereby the deodorization is accomplished in this process are both chemical and physical. The iodine value of the oil treated is lowered to a certain extent and the amount of lowering is proportional to the original iodine value. It is claimed that the process can be successfully operated when the oil comes in contact with nothing but glass and hydrogen during treatment.

SYNTHETIC PRODUCTION OF JEWELS

Practically all of the beautiful minerals of the corundum family are now being produced synthetically. The ruby and the sapphire are the more important.

Alumina being the base of these precious stones, it remains only for the chemist to add the proper oxide to obtain the required colors and to fuse them together in the oxy-hydrogen flame. The ruby, for example, contains 97½ per cent of pure alumina and about 2½ per cent of chromic oxide.

It is absolutely essential that the material be pure, as otherwise the product obtained will be faulty and the color will be poor.

The process is as follows:

Pure iron-free ammonium alum $(NH_2)_2SO_4$. $AL_2\ SO_4\ .24H_2O$, is mixed with a little chrome alum $(NH_4)_2SO_4$. CR_2 $(SO_4)_3\ .24H_2O$, and the whole precipitated in warm aqueous solution by means of ammonia. A mixture of $AL(OH)_3$ and $CR(OH)_3$ (2½ per cent CR_2O_3 gives the best color) is thus obtained.

At a temperature of 1,000° C., the material is calcined in an oven at a bright red heat and removed and reduced to a fine powder. The fine powder is then placed in the magazine (Fig. 2) which then passes through a platinum sieve situated in the oxygen tube of the oxyhydrogen furnace, and then forced down on a receiving base below the flame. The work at this stage is very delicate and requires most careful attention. All conditions must be regulated with mathematical precision; the rate of the flow of the AL_2O_3 powder, which is automatically controlled by an electric magnet; the rate and pressure of the gases; and the quality of the flame 2.537.78° C. With conditions properly adjusted the stone at first appears as a little stalk not larger than a pin head as seen in Fig. 4, which gradually grows in the fire. This stalk, as it grows taller, is broadened by the manipulation of the torch by a skilled operator so as to form a small cone with the point down, *E*. The desired size obtained, the operator shuts off the

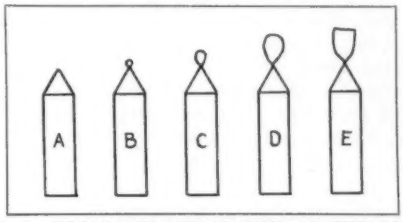


FIG. 4. PHASES IN THE MAKING OF THE RUBY
A, cone of Al_2O_3, *B* pin head, *C* and *D* enlarged boule, *E* jewel formed and ready for cutting

gases and cautiously allows the jewel to cool. It is then broken from the base and is ready for cutfing.

The specific gravity is 3.98 to 4.0, hardness; optical properties, and general character agree with natural rubies.

White sapphires are formed by the omission of the chromium and are pure alumina, AL_2O_3.

BLUE SAPPHIRES

Blue sapphires are made by adding 0.5 per cent titanium dioxide, TiO_2, and 1.5 per cent magnetic oxide of iron, FE_2O_4; the analysis being

AI_2O_3,	99.84 per cent
TiO_2,	0.11 to 0.13 per cent
FE_2O_3,	Trace

Specific gravity 3.977 to 4.01.

Rubies and sapphires besides being used as gems have a very extended use in watches, phonographs, balances, and in delicate mechanism which require hard unwearable smooth surfaces.

HYDROGEN EMPLOYMENT IN QUARTZ GLASS OR FUSED SILICA GLASS

Quartz glass (SiO_2) which has long been recognized as an important material in the manufacture of various articles employed in the chemical industry, was first produced in 1839 by Professor Gaudin. Some of his quartz tubes and elastic threads were exhibited at the Paris Exposition in 1878.

In 1889, Boys, who recognized the possibilities of this remarkable substance, also succeeded in making small tubes and other articles.

However, little progress was made in the development of the quartz-glass industry until 1900, when Heraeus and Achendstone succeeded in making clear rock crystal large enough for practical purposes. The raw material is washed quartz sand containing 95 per cent silicic acid, which is melted by the oxy-hydrogen flame, and it is now possible to melt and to mold into almost any desired form as much as 50 pounds of quartz at a time.

One of the most remarkable properties of the quartz glass produced by this process is its resistance to acids. Even boiling acids, with the exception of hydrofluoric and phosphoric, will not readily affect it. Quartz has the advantage of having a very low coefficient of expansion, consequently silica ware may be made white hot and then plunged into cold water without being affected, being about 1/17 that of the best glass suited for chemical utensils and apparatus.

The methods of manufacture have of late been greatly improved on, but many of these improvements are maintained as trade secrets. So far the industry in this country practically use only the oxy-hydrogen flame for melting the quartz. One of the methods employed is to heat quartz for some time at a temperature of 570° C., which causes it to break up into small pieces, which are afterward fused in crucibles made of iridium or crucibles made of a mixture of zirconia and alumina. The latter being less expensive.

The fused silica is then worked like glass, and flasks of 60 cc. capacity can be blown without difficulty.

The material for casting is accomplished by the use of iridium molds, so as to obtain hollow cylinders which are afterward blown and worked in the oxy-hydrogen flame.

Fusd silica ware at 1,000° C. becomes pervious to gases, at 1,600° C. it softens. Devitrification is induced by prolonged heating at 1,200° C. Short exposure at higher temperatures does no harm. The density of clear fused silica ware is 2.22. For ultra-violet rays it is more transparent than any other glass. Fused silica ware is used in connection with the mercury vapor lamp and in the manufacture of chemical utensils and apparatus. The manufacture of quartz glass in the United States is only of very recent date.

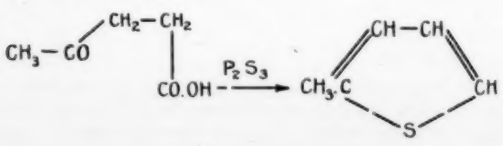
SYNTHETIC RUBBER

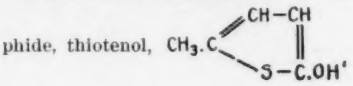
In the manufacture of synthetic rubber it is necessary to first manufacture either one of these three materials, butadiene, isoprene or dimethytbutadiene. These substances are certain unsaturated hydrocarbons which are allowed to polymerize and form a series of caoutchoucs which possess many of the properties of the best sorts of natural caoutchouc, including the power to vulcanizing.

Several processes for the manufacture of isoprene are used, among them one that uses hydrogen. This process is:

Isoprene from starch or sugar through laevulinic acid. The process is highly technical as the reader will observe.

Starch or sugar is converted into laevulinic acid, $CH_3.CO.CH_2.CH_2.COOH$, by boiling with dilute HCl or H_2SO_4, and distilling the acid with phosphorous trisulphide at 130° to 140° C., whereby thiotolene distils over:



If phosphorous pentasulphide is used in place of the trisulphide, thiotenol,  is obtained.

The thiotolene or thiotenol is converted into isoprene by passing either compound mixed with hydrogen over finely-divided copper or iron at a temperature of 300° to 500° C. In the presence of hydrogen the sulphur is eliminated and combines with the metal forcing a metallic sulphide, which is then reduced by the excess of hydrogen to free metal. The final product is isoprene:

THIOTOLENE ISOPRENE

Above 500° C. the isoprene is converted into its polymer-dipentene, $C_{10}H_{16}$.

HYDROGEN IN BALLOONS AND DIRIGIBLE AIRSHIPS

Hydrogen, on account of its very low density, has the greatest lifting power of all gases, and is therefore used for filling balloons. The ascensional force of hydrogen depends on specific gravity, temperature, and the barometric pressure of the atmosphere. A liter of hydrogen gas under normal conditions has an ascensional force of 1.2 grams. The specific gravity of 98 per cent hydrogen is 0.087, which corresponds to a lifting power of 73.5 lbs. per 1,000 cu. ft. Pure hydrogen has a specific gravity of 0.06949, which corresponds to a lifting power of 75 lbs. per cu. ft.

Hydrogen for balloon purposes must be free from impurities that would injure the fabric, and should be dry. It is not necessary that the hydrogen be under pressure for inflating a balloon. It will readily inflate at atmospheric pressure.

Hydrogen for balloons according to history was for the first time used as an experiment August 27, 1783 by Professor Charles at the Champs de Mars, Paris. In December of the same year Professor Charles and his brother Robert, made a balloon ascension in which hydrogen was used.

The use of hydrogen for inflating toy balloons is in considerable demand. The following table of tests which has been recently worked out by actual tests on different size rubber balloons will be found useful in approximately determining the amount of hydrogen required to inflate the various sizes of toy balloons.

Table of Tests on Volumes of Hydrogen for Toy Balloons[2]

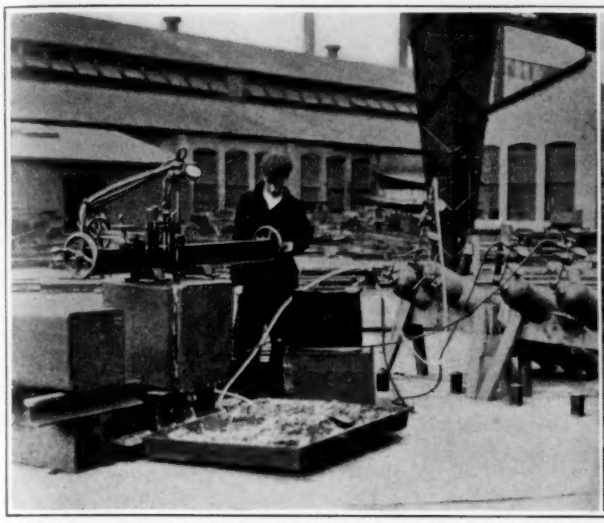
SIZE	No. 50	No. 60	No. 110
Size inflated	6″ to 6½″	7″ to 7½″	9″ to 10″
Hydrogen required for one cubic inch	140 to 170	220 to 250	440 to 550
Cubic foot	.081 to .1	.125 to .145	.25 to .32
Cu. ft. of hydrogen required for one gross	11.7 to 14.4	18 to 21	36 to 46
No. of balloons inflated per 100 cu. ft. of hydrogen units	1,234 to 1,000	800 to 690	400 to 312

Above figures are subject to variation due to: 1. Difference in temperature, 2. Differences in atmospheric pressure, 3. Differences in elasticity of rubber, 4. Differences in rate of charging.

CALCIUM LIGHT

Is used for the purpose of projecting pictures upon screens in illustrating lectures, illuminating and signal purposes.

[2]If charged too rapidly, gas blown into balloon will be cold and on being left standing will acquire a temperature of the surrounding air and increase in volume.



HAND-CUTTING MACHINE, OPERATING ON A 16-INCH BILLET

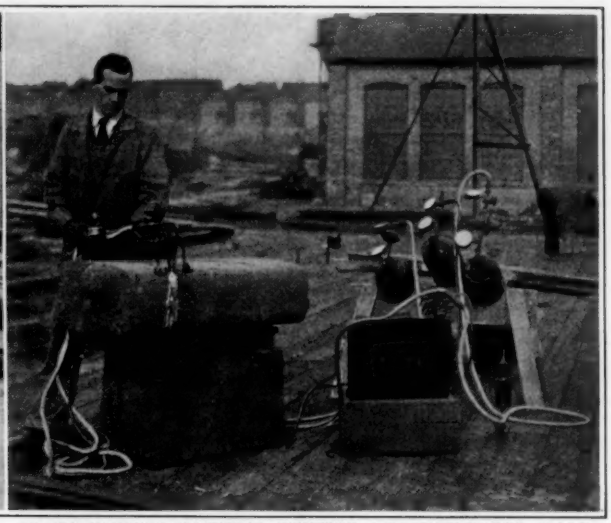


PLATE-CUTTING MACHINE, CUTTING A 24-INCH STEEL BILLET

Oxygen and hydrogen are burned through a special jet which prevents the gases from mixing before they reach the end of the tube where the combustion takes place. It is constructed on the principle of a blow-pipe and gives approximately 1,000 candlepower.

The hydrogen is first passed through and lighted; then the oxygen is passed through slowly, the pressure being regulated from the cylinders and increased until the flame appears thin and straight. This solid flame gives little light but is intensely hot. When the oxy-hydrogen flame is allowed to play upon some substance which it cannot melt or burn, the substance becomes heated to incandescence and gives off an intense light. The substance commonly used for this purpose is quicklime. Hence, the light is frequently called calcium light. It is also known as the Drummond light. Drummond having used it first in 1826.

The temperature of the oxy-hydrogen flame is about 2,537.78° C.

CUTTING BY THE OXY-HYDROGEN PROCESS

The process of rapidly cutting iron and steel with the blow-pipe and a jet of oxygen has been considerably developed, and its application for rapid cutting by oxidation of the metal has only been known industrially for a comparatively few years. It is well known that metals made intensely hot burn easily and rapidly in an atmosphere of oxygen. Iron heated from 1,300 to 1,500 degrees F. has a wonderful affinity for oxygen and instantly combines with it to produce various forms of oxides. Therefore, if a jet of oxygen is directed upon iron that has been brought to a point of incandescence the oxygen oxidizes the metal at the point of contact. In other words, burns it. The design of an oxy-hydrogen blow-pipe especially intended for cutting iron and steel consists of a heating flame and a special ejector of oxygen under pressure. The operation consists of projecting, on the metal previously heated to redness, a jet of oxygen escaping under a sufficient high pressure. The oxide is driven away as it is produced, and the combustion extends throughout the thickness to be cut. Various gases are used as a preheating flame with oxygen in cutting of metals, viz., the commonly used acetylene which contains considerable carbon. Carbon unites with the molten metal and causes an excess of slag to form. Therefore owing to this tendency of carbon to form an excessive amount of slag, gases containing carbon retard the action of the flame, give rough cuts and prevent the action of the flame on the metal from penetrating to any great depth. Thus hydrogen being free from carbon and impurities give a speedy, deep and clean cut with oxygen which is not obtainable from all other gases used in conjunction with oxygen as a preheating flame.

Iron and steel over twenty-four inches may be cut with the oxy-hydrogen flame. For light cutting, the hand torch is used and for the cutting of plane surfaces up to twenty-four inches, the cutting machine is used.

Oxy-hydrogen flame lends itself more than any other process to the preparation of cutting of iron and steel.

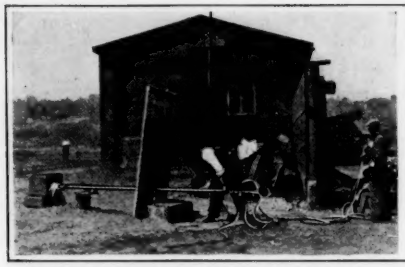
REMOVAL OF METALLIC MASSES BY THE OXY-HYDROGEN FLAME

The speedy removal of metallic masses, such as slag or residue in blast or cupola furnaces, which seriously retards the proper working of the furnace, is often of the greatest importance, and to effect the removal of these masses by ordinary mechanical methods necessitates hours, and even days of very strenuous effort. Obstructed or "frozen" delivery holes are also of frequent occurrence, with a resultant loss of time while the furnace is out of operation, and often a total commercial loss of the charge.

For the removal of objectionable masses within the furnace, or the rapid opening of obstinate delivery holes, the oxy-hydrogen flame is admirably adapted when brought in contact with the combustible slag or other metallic masses at the proper temperature, produces intense heat with the immediate result of oxidation of the heated metal. Thus clogged or "frozen" tap holes in iron furnaces are easily and quickly opened, a hole eight inches in diameter being made at a rate varying from a half inch to an inch in a minute, depending on the depth of the hole. The oxy-hydrogen torch employed consists of a burner head, with four preheating nozzles, supplied with a mixture of pure oxygen and hydrogen and one nozzle located at a certain distance from, and in line with, the preheating nozzles, which are supplied with pure oxygen only. The operating end of the torch is at a sufficient distance from the burner head to insure perfect ease and safety to the operator even while cutting the deepest hole.

A flow of fresh water is maintained which effects a continuous cooling at the burner points, and keeps the entire torch cool. Ordinary city water pressure is ample for this purpose, and is admitted to the operating end of the torch by means of a single light hose. On the operating end of the torch, connections for the water and gas tubes are provided together with valves for the regulation of the water supply and gas for the preheating and oxidizing nozzles.

In the Fig. 5 diagram of the oxy-hydrogen perforating torch, tank *A* contains oxygen and tank *C* hydrogen, both under pressure. *D* and *F* are pressure regulators, which automatically maintain the desired pressure of the two gases at the nozzle *L*, where they are mixed in the proper proportion



MULTIPLE BURNER TORCH BURNING A 5-INCH HOLE THROUGH A 12 X 12-IN. STEEL BILLET 18 INCHES LONG

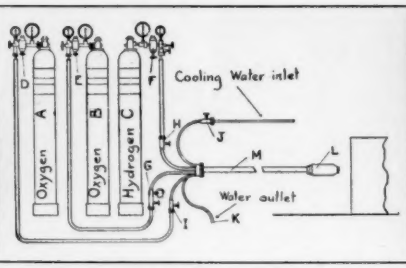
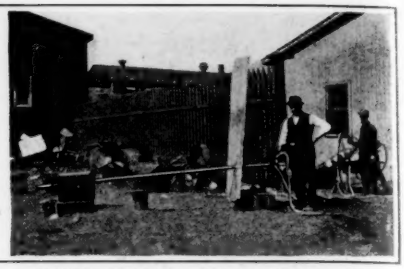


FIG. 5. DIAGRAM OF THE OXY-HYDROGEN PERFORATING TORCH SHOWING CONNECTIONS TO WATER COOLING SYSTEM



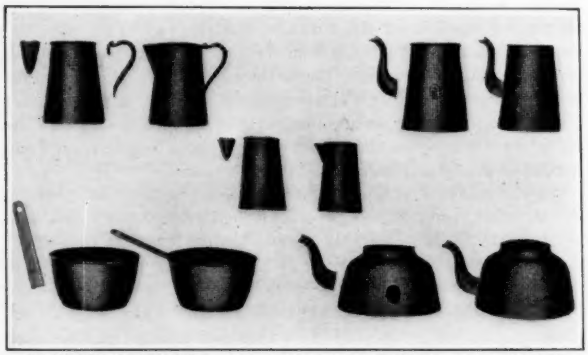
COMPLETION OF THE OPERATION SHOWING TORCH CLEAN THROUGH THE BILLET—WORK DONE IN 12 MINUTES

before ignition, at the one or more nozzles which constitute the preheating flames.

Tank *B* contains the oxygen supply, under pressure, for the single nozzle *L* and is conducted through the regulator *E*, rubber tubing and valve *G* to this nozzle and strikes the metal which has already been heated by the preheating flame, and burns or oxidizes it. *H* and *I* are shutoff valves, for the preheating gases, located on the apparatus. *M* is a pipe casing, *J* the cooling water inlet valve for regulating the water supply which circulates through the nozzle, and *K* is the discharge.

OXY-HYDROGEN AUTOGENOUS WELDING

Oxy-hydrogen autogenous welding introduced for industrial welding in 1901 is a process of obtaining joints by fusion of metal under the action of the oxy-hydrogen blow-pipe flame. It consists in uniting the metal which is in the liquid state, to operate in such a manner that its physical, mechanical, and chemical properties are not seriously modified at the



COOKING UTENSILS, ALL PARTS OF WHICH ARE JOINED BY OXY-HYDROGEN WELDING

place of welding, so that they approach as nearly as possible the properties of the original material. In welding thick pieces, say from 1/8 to 3/16 inch by any of the fusion methods, it is customary to bevel or chamfer the two edges of the joint and fill the "V" thus formed by melting metal from a rod by means of a torch. The technique of oxy-hydrogen autogenous welding does not require great effort to master but it is necessary to learn certain elementary principles and then exercise judgment as each application warrants. The oxy-hydrogen process for welding of thin sheets of iron or steel or special alloys is limited up to 1/8 inch thick, but for welding of brass, copper, lead, aluminum, it is particularly adaptable and is often preferable to oxy-acetylene. The reason for this is that with the high temperature of the oxy-acetylene flame, it is easier to burn these metals than with the oxy-hydrogen flame, the temperature of which is considerably lower—about 2,800 C., and that of the oxy-acetylene flame about 4,000 C.

One cubic foot of hydrogen produces 88 calories or 350 B.t.u., and that of acetylene 410 calories or 1,630 B.t.u. The combination of the two gases may vary in the proportion of one volume of oxygen mixed with from four to six volumes of hydrogen, depending on the style of torch, the skill of the operator and character of the material to be welded.

The following is a table of gas consumption:

Table of Welding and Gas Consumption
(*Oxy-Hydric Bulletin*, p. 28)

Thickness of the Metal in inches	Nozzles welding	Gas Consumption in Cubic Feet for Lineal Foot of Metal Welding		Time for Welding of Metals 12 In. Long	
		Oxygen	Hydrogen	Min.	Secs.
1-32	No. 1	0:08	0:33	2	:00
1-16	No. 2	0:33	1:3	3	:00
1- 8*	No. 3	0:5	2:	3	:30
3-16	No. 4	0:6	3:	4	:00
1- 4	No. 5	0:8	4:	5	:00

*Oxy-hydrogen welding for steel plate over ⅛" is not to be recommended.

The gas consumption and time on material of a greater thickness than ¼ inch cannot be tabulated with any degree of accuracy, as much depends on the nature and class of the weld.

LEAD BURNING

The standard technique of lead burning is similar to that of oxy-hydrogen welding and can be defined as autogenous welding, as the parts are joined by melting the end of a strip of lead of the same composition as the lead plates to be united.

The gases used in lead burning are usually oxygen and hydrogen, both gases under a pressure of from one to two pounds per square inch, in a torch designed to mix the gases in the correct proportion. The oxy-hydrogen flame is applied directly on the strip of lead and is also allowed to play at the same time against the edges of the work until the surface of the lead plates are softened almost to the point of running and the strip of lead is melted in small portions so that a drop at a time of the lead will fall into the joint, thereby making a union in the plates. Considerable judgment and experience are required by the welder to obtain results, as it is necessary to remove the flame constantly from the work. The flame must have a very fine point to obtain satisfactory results.

Hydrogen and air or oxygen, also oxygen with acetylene, or illuminating gas are used in a limited way for lead burning. It is claimed by those who have used air, acetylene or illuminating gas with oxygen, that the combination of oxygen and hydrogen is superior.

OXY-HYDROGEN PLATINUM MELTING

In the melting and welding of platinum the oxy-hydrogen burner is used almost exclusively. The great advantage of this flame is that it contains no elements injurious to the platinum such as carbon. Illuminating gas was formerly used instead of hydrogen. The operation is carried out by

passing oxygen and hydrogen at high pressure through an especially constructed oxy-hydrogen torch. The author devised a torch for this work several years ago, and it is practically the only platinum melting torch (oxy-hydrogen) used to today in the United States by platinum smelters. The melting is best accomplished in a lime crucible. Oxygen and hydrogen at a pressure of 1,800 pounds per square inch in cylinders containing respectively 100 and 250 cubic feet with reducing valves and regulators are used. (See Fig. 3.)

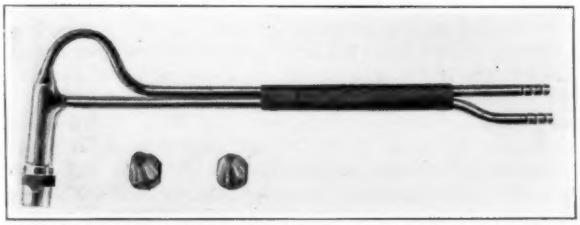
On account of the tendency of platinum to absorb hydrogen and consequent bubbling of the surface, it is necessary to keep a slight excess of oxygen in the flame. Unless care is exercised to have the component gases (oxygen and hydrogen) present in approximately the necessary amounts for perfect combustion the platinum becomes more or less brittle, depending upon the amount of hydrogen retained.

PRE-TREATMENT OF STEEL IN NICKEL PLATING

One of the chief difficulties encountered in nickel plating of steel which has a tendency to scale or peel off has been overcome by the use of hydrogen.

The process is carried out approximately on the following lines (see Fig. 6), the process being continuous:

The sheet steel in a roll is passed first through a chamber of hot hydrogen, which reduces all oxides and gives it a fresh surface. From this chamber it is passed into a second chamber which is a cooling chamber containing hydrogen; it is then placed in the nickel bath and through the wash tank; then again through a third chamber where it is raised to welding heat; and finally to a cooling chamber. The speed is gaged to allow each step of the operation sufficient time.



OXY-HYDROGEN TORCH WITH TIPS FOR MELTING VARIOUS QUANTITIES OF METAL

The working out of this problem has been of great importance to the manufacturer who is welding nickel-iron sheets.

MANUFACTURE OF TUNGSTEN AND MOLYBDENUM

Tungsten and molybdenum in the early stages of their history were produced from their oxides by reduction with alkaline metals. Woehler, as a rule, has been given the credit of having first produced metallic tungsten, but a close study of the literature divulges the fact that metallic tungsten was known and has been produced by this same method as early as 1790.

During the latter part of the nineteenth century, tungsten and molybdenum were produced by reduction from their oxides with zinc and carbon, and tungsten for technical purposes is even now chiefly produced by the carbon reduction method.

Wherever tungsten and molybdenum of high purity are required, both metals are now produced by reduction with hydrogen.

Tungsten in particular has grown during the last decade in importance and the modern illuminating problem can be said to have been solved only by the aid of tungsten. A tungsten filament lamp, that is the incandescent lamp having an illuminating body or filament which consists of pure metallic tungsten, has not only completely displaced the old carbon filament lamp, but has also popularized the electric light as against the gas light and is slowly but surely displacing the arc light from the street.

This success of the tungsten incandescent lamp is in turn due to some extent to the development of the production of pure hydrogen on a large scale and at a comparatively low price. While it is possible to obtain pure tungsten by other methods, the reduction by hydrogen undoubtedly is the most convenient one and from the point of view of purity of the product is the most important one. Both zinc and carbon, if used in excess, remain in the tungsten as impurities, whereas, an excess of hydrogen is not in any way harmful to the tungsten on account of its gaseous nature.

For the production of tungsten and molybdenum the trioxides of the metals WO_3 (tungstic acid) and MoO_3 (molybdic

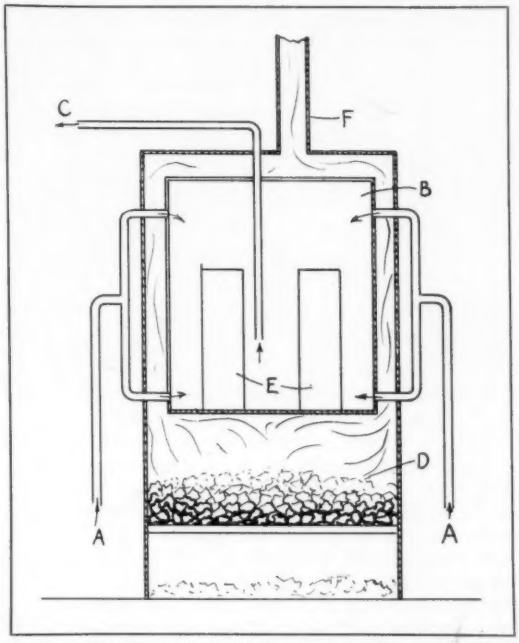


FIG. 6. ANNEALING FURNACE FOR SHEET STEEL TREATMENT BEFORE NICKEL PLATING

AA, source of hydrogen supply; *B*, chamber for heating steel in hydrogen; *C*, spent hydrogen outlet; *D*, fuel chamber; *E*, rolls of sheet steel; *F*, flue.

acid) are employed. Both are obtained from their ores wolframite, scheelite, hubernite or ferberite (in the case of tungsten) and molybdenite or wulfenite (in the case of molybdenum), by well known methods. The oxides as a rule are placed in boats and these boats are passed through tube furnaces which are heated externally either by electricity, gas burners, or in some other convenient manner, the tube temperature varying from 500° to 900° C. The exact tem-

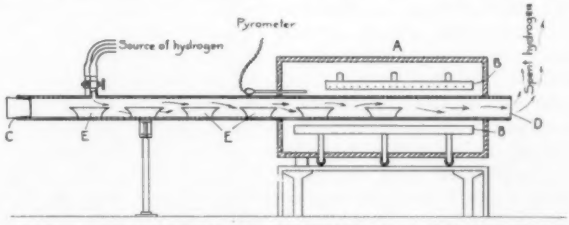


FIG. 7. FURNACE FOR REDUCTION OF TUNGSTEN AND MOLYBDENUM

A, furnace (insulated); *B*, heating burners; *C*, openings for inserting boats; *D*, opening for removing boats; *E*, boats

peratures are different for the two metals and are of importance if the final structure of the resulting metal powder is to be considered, but principally and for the present purpose they are negligible. Through the tube there is passed during the entire heating period, a stream of dry hydrogen. The hydrogen combines with the oxygen of the oxides and forms

water which is carried away by the flowing hydrogen in the shape of steam, leaving behind in the boats metallic powder of tungsten or molybdenum. A photograph of such an apparatus is reproduced at the head of page 341 and a diagrammatic sectional view is shown in Fig. 7.

The metals in powder form serve for only very few purposes. Molybdenum, and particularly tungsten, is used as a rule in the form of solid bodies, particularly as wires in electric incandescent lamps, where tungsten forms, as mentioned, the lighting body or filament, whereas, the supporting holders or hooks are in most cases formed of molybdenum wires.

Tungsten has found a great many other applications during the past decade. It has replaced platinum as a make and break contact in ignition systems and most automobiles are now equipped with tungsten contacts. Other important uses of tungsten are X-ray tubes, wireless outfits, dental purposes, and many other uses of vital importance.

Hydrogen is being used during almost the entire process of transforming metallic tungsten powder into the various shapes in which it is finally used. The metal is heated repeatedly for the purpose of facilitating the various operations carried on with it and if these heating operations were to be done in the open air, the metal would oxidize. It is, therefore, necessary to protect it by surrounding it with an inert atmosphere. As such, hydrogen is the logical one, it having been used in the production of the metal. Furthermore, hydrogen was recommended by the art for the same and similar purposes a considerable time ago, as for instance by Vaugeois in the French patent 168106 in 1885.

During the various processes which tungsten undergoes before being formed finally in the desired shape, hydrogen is applied in a number of machines and apparatus which are used. The principle is to surround the metal during the operation with a protecting atmosphere of the hydrogen and for this purpose bells or containers have to be constructed into which or through which hydrogen is passed.

The hydrogen which is used for these purposes is either taken from steel containers of the usual form, or in most instances produced in the manufacturing plants.

NEWEST USES OF HYDROGEN

The following references to new uses of hydrogen may be of value:

Liquid hydrogen for fuel in engines. Rome, May 7, 1920. *New York Tribune.* Italy.

Synthetic benzine. Compressed Gas Mfg. Association *Bulletin*, Dec. 23, 1920. Germany.

Turpentine and varnish substitute. *Rev. Chim. Ind.* 29, 173-8 (1920), *Chemical Absts.*, Vol. 14.23, p. 3,803. France.

SYNTHETIC PRODUCTION OF PETROLEUM

FOR many years we have been the great petroleum producer. The world could not have progressed as it has during the last fifty years had it not been supplied with American petroleum. At home these oils have enabled us to develop agriculturally, industrially and in many other ways in a marvelous manner. Let us now awaken to the fact that unless something revolutionary occurs, all this will be changed. Sir E. Mackay Edgar, an English authority, recently made this statement: "In ten years' time America will be forced to buy annually from Great Britain 500 million barrels of oil." This is a most startling prediction, and, if it be fulfilled, might spell disaster to many of our interests—hence we must examine the facts and see if it is likely to occur. In my own efforts to do this, I have gone over the figures showing the petroleum marketed during the last forty years and have found, in round numbers, as follows: In 1898 it was 55 million and in 1918 it was 350 million barrels. From these statistics we learn the consumption during the twenty years from 1878 to 1898 increased 266 per cent, and that during the next twenty years the increase was 536 per cent, and if we assume the increase during the last twenty years, it will have increased 268 per cent over the figures for 1918 by the year 1928, which would make the consumption no less than 938 million barrels. It may be said this amount will not be required in the United States as foreign countries will be producing their own oils; but it is quite certain the increased use of petroleum as a substitute for coal in producing power for vessels and manufacturing plants will more than make up for the lost foreign trade.

It would seem that Sir E. M. Edgar's prediction would come true unless we do some things we are not now doing. There are possible ways of avoiding this calamity. The immense oil shale deposits in our Western States form a source of supply of petroleum, but, unfortunately, there are great difficulties to overcome in their utilization. A ton of shale would yield approximately one barrel of oil, hence 938 million barrels of oil per year would require the working up of 938 million tons of shale each year, and this is well-nigh twice the amount of coal mined in the United States in one year. All this shale would have to be retorted to distill off the oil, and it is difficult to believe this possible, and certainly it is not possible within the ten years, and probably not in twenty. We have not the man power to do it with, and in the meantime we are rapidly approaching the exhaustion of our natural petroleum.

Certainly this whole situation has a serious aspect, but I think we can find a favorable solution. Petroleum is a compound of carbon and hydrogen in about the proportions of eighty parts carbon to twenty parts hydrogen. The carbon and hydrogen in this shale as mined from the earth have not yet united to make petroleum, but the simple act of heating the shale causes them to unite and form petroleum which can be distilled off.

It would be belittling man's mental power to assume he cannot learn how the carbon and hydrogen are associated in the shale rock and be able artificially to produce this combination in such quantities as he desires. Carbon and hydrogen are elementary substances to be had, the carbon from our coal, even of the lowest grade, and the hydrogen from water, and we may consider them inexhaustible. This problem can, and undoubtedly will be solved by some one of our 15,000 or more chemists, but it is, in fact, a national problem, and could come under Government supervision. It would well justify the offering and payment of a handsome reward for its early solution.—Abstract of a paper by Dr. Edward G. Acheson, read before the Waterpower League of America.

COOLING OF LARGE ELECTRICAL MACHINES

ELECTRICAL machines of high specific power, such as turbo-alternators, have hitherto been generally cooled by simple air circulation.

This system has several disadvantages, the chief of which are the difficulty in eliminating dust, and the risk of spreading fire present when large volumes of oxygen are being driven through the windings. Other systems have been recently proposed, such as the addition of surface or water-jet cooling radiators for the circulating air (*General Electrical Review*, Feb., 1920), and direct water cooling by water led through pipes and cavities in the machine frame. These proposals are criticised by the present author—the first as exceedingly cumbrous and as not removing the risk of fire, while adding (in its alternative form) the risk of humidity, the second as still necessitating air for the cooling of the rotor and the bulk of the stator.

The author, in collaboration with M. Corblin, has been working for a long time past on a new system which he has just patented, in which the cooling is effected by a suitable volatile liquid led to the parts to be cooled, where it is vaporized, then condensed and used again. This process permits, at least theoretically, the collection of the heat produced in an electrical machine, part in the form of motive power and part in the form of useful heat. Among the liquids suggested and discussed are carbonic anhydride, sulphuric anhydride, and methyl chloride.—P. Bunet, *Revue Générale de l'Electricité*, Sept. 4, 1920. Abstracted by *The Technical Review*.

THE FASHIONING OF MANILA HEMP INTO "SLIVERS" PREPARATORY TO SPINNING THEM INTO STRANDS

Manufacture of Rope and Twine

Treatment of Manilla Hemp, Sisal and Jute in a Modern Rope Factory

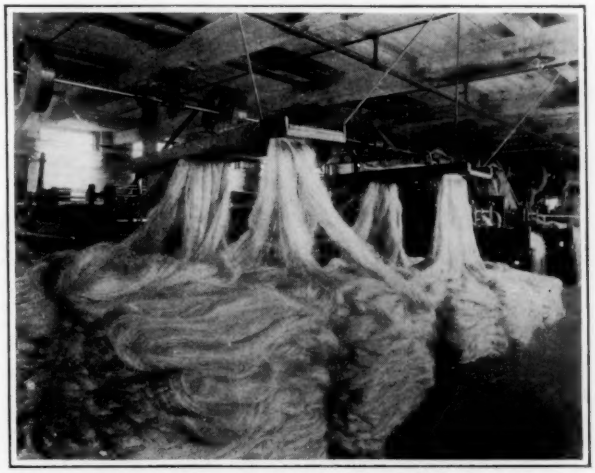
By S. G. Williams

Photographs Copyrighted by Publishers Photo Service

In our last issue Mr. S. G. Williams described the primitive methods employed in obtaining hemp from the wild banana plant. The article is here supplemented with the story of what is done with this hemp, as well as other rope fibers, after reaching a modern rope factory.—THE EDITOR.

BEFORE touching upon the mechanical side of this subject, let us discuss sisal and jute which, after reaching the factory, are subjected to the same processes as those employed in the production of cordage from hemp. It is from Yucatan, Mexico, that we get most of our sisal fiber, where climatic circumstances and an ideal soil combine to yield annually anywhere from 750 to 900 pounds of fiber per acre. The heniquen plant, from which sisal is got, is one of the cactus family, and from the trunk of the growth project an array of sword-like leaves containing the desired fibers. A vigorous heniquen will continue to produce good leaves for a decade; and its yearly crop will range between 20 and 30 leaves. The plants are all grown from sprouts set in rows from 8 to 10 feet apart, and reach a cutting stage in about five years. Care must be taken to see that the heniquen is not permitted to flower, because the blossoms reduce the sap in the leaves and cause them either to wither or to yield a fiber of a much reduced strength. Similarly, the plants after they are ten years old lose their vigor, and the sisal filaments reflect this decadence.

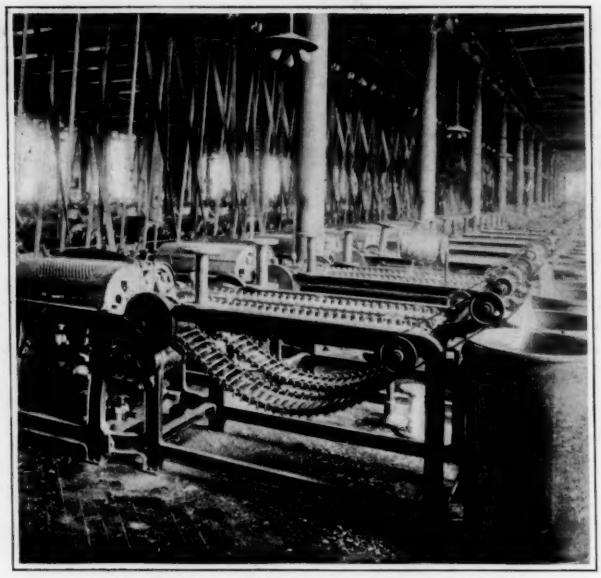
In harvesting sisal, the natives cut off the leaves, one by one, with a large and heavy knife, and a day's work for a field hand varies from 2,000 to 3,000 leaves. After the spiny leaves have been chopped off from the parent plant, they are tied in bundles ready for transporting to the decorticating machines, which strip off the pulpy material preparatory to washing the fiber. The filaments are next washed and then hung up to dry in the sun. When thoroughly dried and bleached, the heniquen hemp, as it is sometimes called, is baled by a press, covered with cloth and made ready for shipping. Sisal fiber is not equal to Manila hemp in flexibility, and the filaments are shorter and have a tendency to splinter. A good grade of sisal is something like 75 per cent as strong as a corresponding grade of Manila



PREPARING THE FIBER FOR SPINNING

hemp, and for this reason it is not used in ropes where much strain is likely to be encountered or where wearing quality of a high order is expected. Sisal rope finds its greatest service in agricultural activities and wherever the requirements are not over exacting.

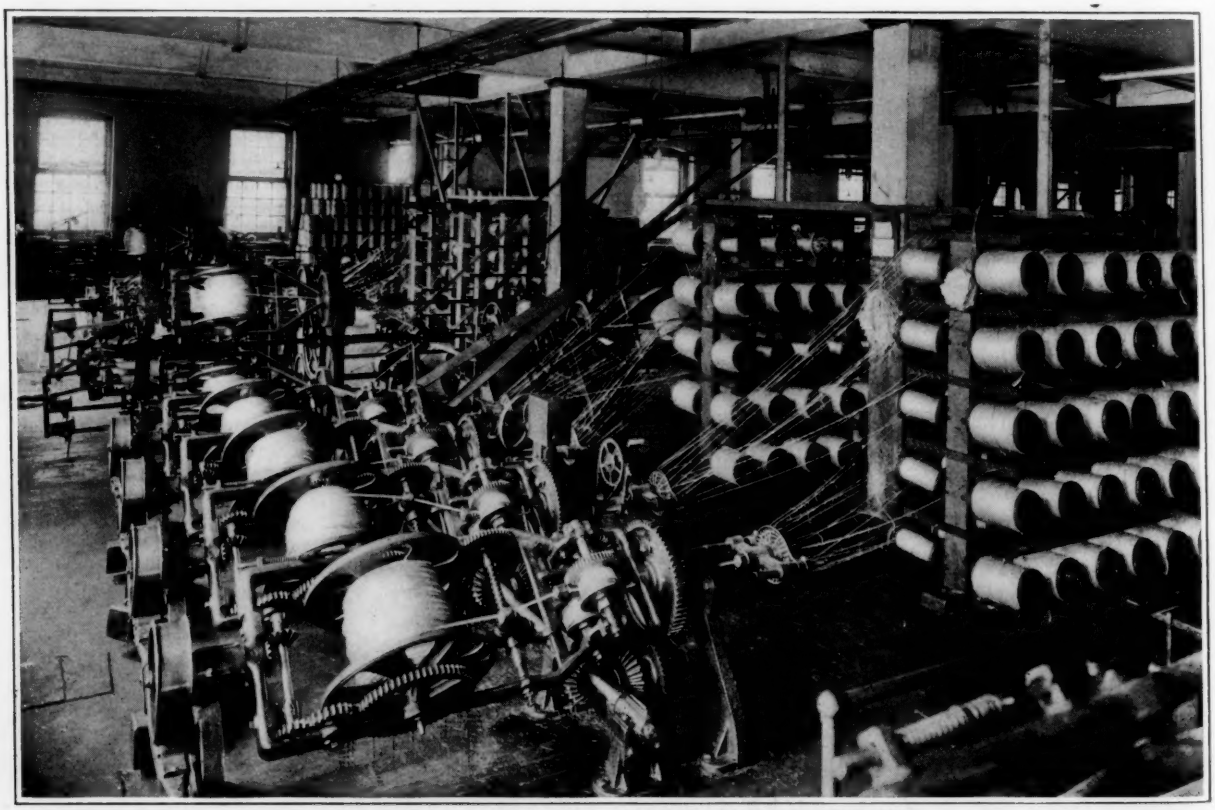
But for the farmer's need of a binding twine, suited to the operation of the mechanical harvester, we might still know little if anything about the virtues of heniquen. So recently as forty years ago, one large rope works in Pennsylvania brought out and marketed a binder twine fashioned entirely from sisal, and in doing this followed immediately in the footsteps of William Deering. The year before, Deering had put his harvester to a test in the Western wheat fields, and his principal difficulty was the lack of a twine of marked and uniform strength. It wasn't until he made twine of sisal, experimentally, that he hit upon the thing needful to the satisfactory working of his ingenious labor-saving apparatus. He blazed the way for a domestic industry which now produces fully $25,000,000 worth of binder twine each twelve months. The world over, a matter of 600,000,000 pounds of twine and rope of the lower grades are called for in dealing with the annual harvest of cereals.



MACHINES FOR COMBING AND STRAIGHTENING THE FIBER THREADS

Yucatan produces normally a million bales of heniquen; and most of the crop is bought by us and worked up by our cordage factories.

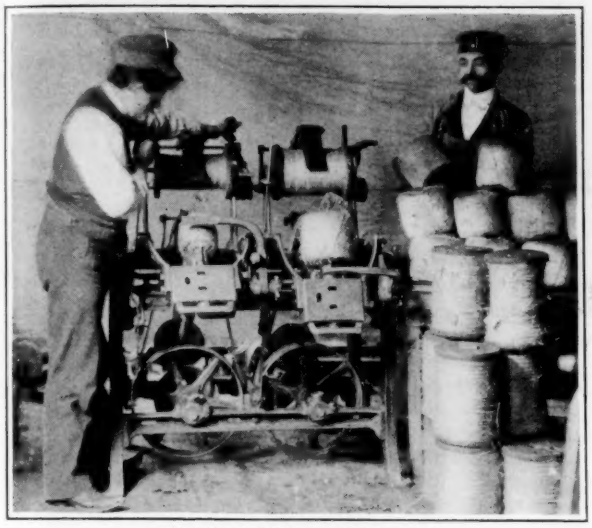
Jute figures conspicuously in the manufacture of a great variety of twines and rope for special purposes, such as for clothes lines, halters, tent ropes, bed cords, etc. The fiber comes from a plant grown in the main in a certain section of India, and the filaments are separated from the enveloping vegetable substance by retting. The stalks are from 10 to 15 feet long, and are immersed in water for a period of about ten days. The resulting fermentation makes it easy to strip the fibers after the removal of the slimy mass from the retting pool. When the filaments are cleaned, dried, and duly graded, they are made into hanks, baled, and then shipped abroad. The objectionable feature about jute, apart from its inferior strength when compared with hemp or sisal, is its tendency to absorb moisture from the surrounding atmosphere, which causes it to expand and contract according to the state of the air. In passing, it may be said that the growing of jute of a superior character is entirely practicable in some of the southern parts of the United States; and there is reason to believe that its cultivation may be brought to a



A BATTERY OF MACHINES FOR SPINNING THE ROPE STRANDS

point here which will make us well-nigh independent of foreign sources of supply. And now for the manufacturing processes by which hemp, sisal, and jute are worked into cordage; and for the sake of simplifying the story let us deal alone with the handling of the prime raw material, hemp.

After bales of Manila hemp have been duly sorted at the



WINDING TWINE INTO BALLS

factory, the fiber goes into the preparation rooms of the establishment, where it is cleaned and combed by an array of machines variously known as breakers, spreaders, draw frames, and finishers. These apparatus are fundamentally alike in principle and differ only in operative details which serve progressively to comb out and to straighten the fibers and to give them, the while, a characteristic soft and silky appearance. The machines have movable belts composed of bars studded with steel pins—the pins becoming more numerous and smaller as the combing stage progresses. In its final state, the hemp flows from the funnels of the apparatus in a stream of loosely associated filaments, known to the trade as "sliver," and this is deposited into tall metal cans.

The next step takes the slivers to the shipping room, where the tresses of hemp are further subjected to combing and straightening, and are then twisted into "yarn." Simple as this sounds, much care must be exercised to see that the spindles turn out yarn of uniform size. The yarn is taken from the spindles and wound mechanically upon large bobbins or spools. Yarns for various sizes and kinds of ropes differ, of course, as to thickness and grade as well as in the number of fibers worked into them. The operatives in charge of these machines in the spinning room are highly skilled, and upon the thoroughness of their supervision depends in no small degree the fitness of the ultimate cordage. In short, the final rope is strong or weak according to the sturdiness of its basic unit, the yarn.

With the yarns available, the rope maker then chooses just the right number of them to form a "strand" of a given size. In the parlance of the cordage manufacturer, and likewise in the language of knowing rope users, the strand is the classifying element, and the number and getup of these in a rope is fixed in accordance with the service for which the line is designed. The several yarns—fed from their respective bobbins—are led through a draw frame, which guides the yarns while they are being twisted into strands. The cunning workman sees that his strand is subjected to the right tension and that it has just twist enough to insure the specified strength and elasticity. For general purposes, ropes are made of three strands, but when greater strength is needed, four strands are employed, and these may envelop a central core or heart. To meet particular requirements, ropes are fashioned of six and nine strands—the latter really being three three-strand ropes twisted into a single cable. In a nine-strand cable or hawser, the three ropes are laid into one by being twisted in a direction opposite to that in which the unit strands of the separate ropes are twisted. This makes for greater elasticity and produces increased wearing surface. A rope may be "hard" or "soft" laid, and this is determined by the amount of twisting, which naturally stiffens the line.

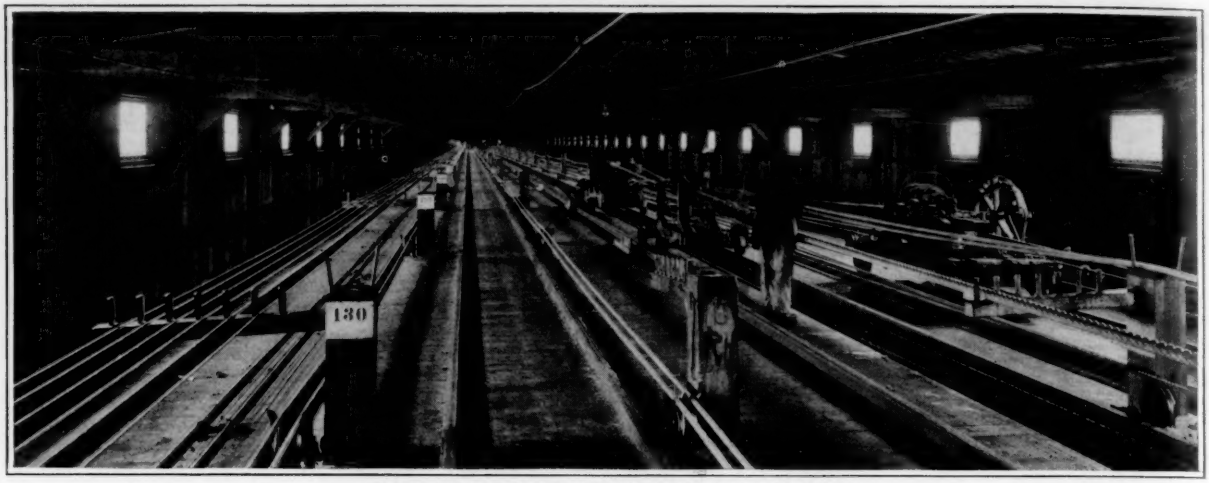
When a rope of a prescribed size and length is finished it is then wound into coils by machine. Towing hawsers, 15 and 16 inches in circumference, are made ready in this way for shipment, and each of these coils will contain 1,200 or 1,500 feet. Coils of lesser lines will hold from 2,000 to 3,000 feet of rope. These coils are strapped or bound by smaller cordage, and, for their better protection during storage and transportation, they are covered with bagging and stamped with the necessary descriptive text and the name of the manufacturer. In the composition of a drilling cable, 2¼ inches in diameter and 3,000 feet long, as many as 25 bales of Manila hemp are used. Cables of this kind are employed extensively in the search for petroleum in our oil fields, and in this realm of industry the ropes are obliged to withstand sudden and severe stresses.

Rope is laid or twisted by two methods: one wherein all of the operations are performed by machinery and the other by a combination of manual work and mechanical facilities. The latter is a development of the oldest procedure, and is still called "walk-laid." In former days, walk-laid rope was entirely a hand product, and the craftsman first built up his yarns from the fiber, next formed them into strands, and finally twisted them into rope while afoot and in motion—walking backward as he added inch by inch to the cordage. Nowadays, the rope-walk really relies upon various apparatus that travel upon tracks from end to end of long buildings extending far enough to permit of the fabrication of single cables, etc., measuring 1,500 feet. It is probably true that human supervision is more intimate and wider during the production of walk-laid rope than in the case of machine-laid rope, but

THE FIRST STEP IN MAKING A ROPE

Four strands of yarn are run into one machine which twists them into a single rope

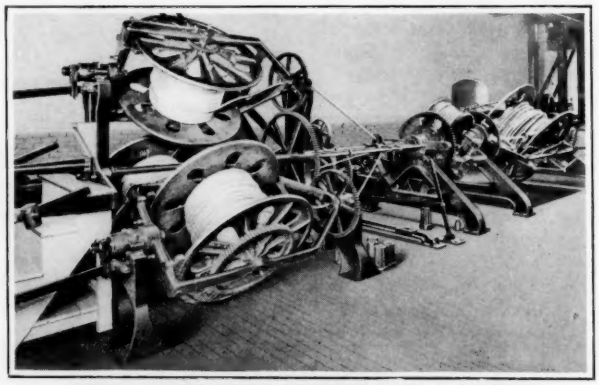
the makers of the latter call to their aid highly trained workmen who are able to see to it that the machines function to a nicety in developing the tension suited to the twisting of the several strands. What this tension means has been made clear by one of our greatest cordage concerns. As explained by this enterprise: "Unless absolutely equal tension is put on all the strands, the rope will never have the tensile strength that it should, for, if one strand is run in slack or given



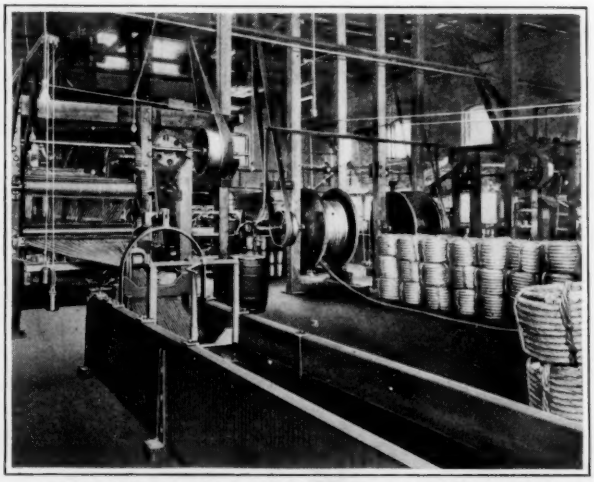
A ROPE WALK WHERE VERY HEAVY ROPE IS MADE

an excess amount of tension and held back, when strain is put upon the rope, it will either not bear its proportion of the strain or will take all the strain. In either case, the rope will not last so long as one in which all the strands bear the strain proportionately. That is why exact tension is one of the most important factors in the making of a rope."

In order that certain kinds of cordage may meet successfully the varying conditions of service, it is necessary to lubricate its constituent members during manufacture. A moment's thought will make the reason for this apparent. Plainly, the wear and tear upon a rope takes place both within and without. The internal wear is set up by the bending of the fibers and their frictional contact with one another, and this action is augmented when the rope becomes dry and fuzzy through use. To neutralize this, lubrication is resorted to; and a line properly lubricated in the making will outlast several dry ones. Although Manila fiber is by nature tough and strong, it becomes rough and harsh when dry. A suitable dressing, however, will render the filaments silky and smooth and thus greatly lessen friction. In passing it should be said that Manila hemp is the fiber par excellence for marine purposes because it will withstand alternate drying and wetting and is not harmed by exposure to salt water. In this respect it is radically different from sisal, its nearest competitor. No wonder, then, that there is an undiminished demand for Manila hemp; and the annual production of something like 100,000 tons in the Philippines is readily disposed of by the growers. To render sisal more nearly comparable with hemp in the manufacture of some small ropes, cords, binder twines, etc., it is the practice to waterproof the yarns by running them through a bath of heated tar.



THREE ROPES BEING TWISTED INTO A SINGLE HEAVY HAWSER



WATERPROOFING ROPE STRANDS IN A TAR BATH

In the trade, the sizes of fiber ropes are designated by their circumference, which is roughly three times that of their diameter, while wire ropes or cables have their sizes fixed by their diameters. The reason for this is to prevent confusion when ordering or referring to ropes without mentioning whether they be of fiber or metal composition. For the sake of those curious about the strength of cordage, the following brief table shows what was produced by one of our large manufacturers in meeting the specifications of the United States Government. Something like 1,500,000 pounds of lines were purchased in connection with a great national engineering undertaking, and the tests prescribed were of a very exacting character.

Circumference Inches	Strands	Required breaking strain, Pounds	Actual breaking strain, Pounds
¾	3	1200	1316
1⅛	3	1900	2100
1½	3	2500	4150
2	3	4000	5400
2¼	3	5000	6750
3	3	7800	10400
3½	4	10500	13200
3¾	4	12200	16100
4½	4	17400	21300
5½	4	27700	30000
6	4	31000	35600
7½	4	42300	45000
9	4	60000	77200

It would take a long list to enumerate the many ways in which fiber ropes figure in our daily and industrial life.

THE "EXPRESS" TYPE OF CONTAINER CAR WITH NINE FIRE- BURGLAR- AND WEATHER-PROOF STEEL CONTAINERS

Carloads of Safes

Using Portable Steel Compartments for Transporting Freight by Truck and Rail

"CONTAINER cars"—newly-invented types of rolling stock unlike any hitherto known on American railroads—which provide for radically changed methods of handling less-than-car-load lots of freight, have just been placed in regular service by the New York Central Railroad on its main line between New York and Chicago, with conspicuous satisfaction to shippers. The success attained by these cars in quick, safe, economical handling of valuable "l c l" freight and express on their first score of round trips, indicates the early extension of the system which means a revolution in the methods of handling such package freight throughout the country.

The container cars provide for the complete coordination in service of the three factors in transportation—the steam railroad, the motor truck and the electric railway. They are specially-designed cars carrying portable steel compartments of differing uniform sizes which are so devised as to be transported between the shipper's door and the railroad freight station and kept securely locked in transit. This in effect extends the rail head right up to the door of the consignor and consignee.

The prime purpose of the new container car system is greater security for shipments against loss and damage by theft and by wear and tear, great economies in time and labor expense, as well as reduction in loss and damage, by the elimination of many processes of rehandling from store or factory to truck, thence to freight platforms or warehouses and thence to the freight cars which are easy prey for burglars.

Losses of freight by theft and damage have grown so tremendously in recent years as to present a formidable problem to the railroad managements, and the organization of large and expensive police systems, as well as special educational campaigns among railroad employees and shippers to secure greater safety, better packing and more careful handling, seemingly have been ineffective in checking the steady advance of this wastage. The extent of this item of economic waste can be realized when it is known that for the year 1914 the American railroads paid out $33,000,000 to liquidate claims of loss and damage of freight, and this sum had grown to $125,000,000 for the year 1920. The cost to general business of such losses is not entirely covered, however, in the mere total dollars paid directly by the railroads in claims, and merchants and manufacturers, both buyers and sellers of all classes, are affected by the tremendous leak.

The new system is designed to make goods transportation as safe as is humanly possible for the entire journey from consignor to consignee, by providing an almost impregnable container—an individual private section of a car, for the entire journey between the place of business of the shipper and receiver of freight. This provides the "store door delivery" so long aspired to as ideal railroad service, but which up to now has never been brought to the point of actuality.

The container cars just placed in regular service are of different types, adapted to various commodities and speed schedules, the "express" type being built for handling in passenger trains and the "freight" type of standard construction for use in freight trains.

The "containers" or portable sections are like huge steel safes or boxes that at point of loading or destination may be lifted by means of cranes between the railroad car and motor trucks or electric cars. These containers not only have upon their doors strong locks that may be secured by the key of the shipper himself after loading, but when placed aboard the specially designed car the compartments fit down behind a strong steel bulkhead or fence which prevents the opening of their doors without the hoisting of the whole compartment. A very large incidental economy is expected to be realized through elimination of the necessity of boxing and crating of shipments, the cost of such packing cases being itself a formidable item. A container deposited at the shipping room of a consignor may be loaded direct from the shelves with goods in cardboard or other fragile packages with assurance that they will not be crushed nor touched until the consignee unlocks the steel compartment at his own door and removes the goods.

Several processes of billing and checking, engaging the services of numerous employees, obviously are eliminated by the container system. At present shipments of varying sizes must be checked out and receipted for in the first instance from shipping room to truck, from truckman to the receiving clerk at the railroad freight depot and again from the freight platform via hand trucks into the box car. All this is done away with by the new method, each shipper having an individual section of the car under separate lock, so that chance for loss, theft or damage is reduced to a minimum.

Still another economy to railroad transportation, and perhaps the greatest one, is the additional service that may be secured from rolling stock and terminal space. In busy times, when demands for transportation exceed the capacity of equip-

ment and terminal facilities, the problem is to keep the wheels of every freight unit turning and traffic flowing without interruptions which bring congestion and stalled tonnage. The time of detention of freight cars at terminal points for loading and unloading is a big factor, and labor shortages, the inaction of shippers and limited track and platform space have in the past combined to produce congestion that restricted the carrying capacity of the railroads when the utmost of service was needed. With ample supplies of containers on hand at terminal points for use of shippers at their places of business, these containers affording the utmost of protection to goods, there will be no need for cars to stand idle in overcrowded terminal yards and the time of loading and unloading will be reduced to a minimum. The clearing of a container car by the hoisting of the containers to and from trucks can be accomplished in a fraction of the time necessary to load and unload a box car by means of hand trucks. The container car, furthermore, need not be placed at a platform, but may be loaded or unloaded by means of cranes at any point accessible to either motor trucks, drays or flat cars of electric railways.

With the growth of large cities, terminal track capacity has become more and more a factor in governing the extent of railroad service, and congestion at these points during recent years of intensive transportation activity seriously slowed up the flow of traffic and kept waiting tonnage that otherwise might have moved freely. At some points expansion of terminal facilities has practically reached its limit because of the encroachment of city developments and this has made imperatively necessary the devising of some means for keeping the mass of rolling stock moving almost continuously, if the essential loads are to be transported.

In recent operations of the "express" type container car between New York and Chicago the containers were removed from car to motor truck in from thirty seconds to ninety seconds each, although the most adaptable special crane equipment is not yet in the service, and plans for zoning which will assure the utmost expedition are not yet in effect. This cleared the car of load in a maximum of fifteen minutes.

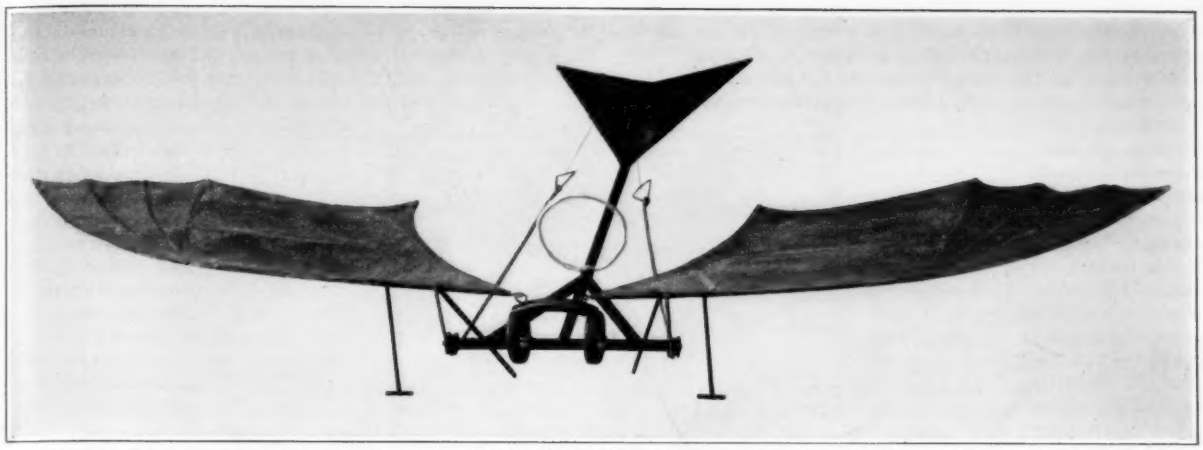
The "express" type car is 63 feet in length, carries nine containers of uniform size, and has trucks, underframe and fittings that make it interchangeable with standard passenger equipment for use in any passenger train. Each of the nine containers is 9 feet wide by 6 feet long, with an inside clear height of 7 feet 4 inches and a door 3 by 6 feet. The steel containers are fireproof, burglarproof and water tight, with a carrying capacity up to three tons each. They have wooden floors and special attachments and reinforcements for convenient lifting and handling.

The "freight" type car is provided with containers of two sizes—15 feet and 7½ feet in length—so that three of the large or six of the small freight containers will fit aboard a 50-foot freight car of standard equipment. The containers in both classes of car into grooves that prevent shifting in transit.

THE BRUNNER, MOND DECISION

THERE has been much interest expressed in the suit brought by one of the stockholders of Brunner, Mond and Company who would restrain the company from making a gift of one hundred thousand pounds for educational purposes. The matter first gained publicity through the difficulty with which the directors obtained their first vote authorizing that this fund be made available for the furtherance of research, since in the first meeting the recommendation of the directors was voted down only to be carried at a subsequent meeting. The suit was brought on the ground that the company had no right to spend money except for its own benefit and since the support of research would not only benefit the company but necessarily a number of others, the proposal to establish the fund was contrary to laws governing the action of the directors in the utilization of corporation funds. Fortunately for research and education, the action has been dismissed by the judge and preparation had been made to appeal the case to the House of Lords should an adverse decision have been rendered. Plans were under way, also, to introduce a plan in Parliament to legalize such gifts. It has become recognized both abroad and at home that our educational institutions cannot train sufficient chemists and other scientists without generous donations not only from individuals but from corporations and it is very fortunate, therefore, that this precedent should have been established through process of law.

HOISTING ONE OF THE COMPARTMENTS OUT OF A MOTOR TRUCK AND LOADING IT UPON THE RAILROAD CAR



LEONARDO DA VINCI'S FLYING MACHINE A. D. 1490, FROM A MODEL IN THE U. S. NATIONAL MUSEUM AT WASHINGTON
Actual size: Length from tip to tip, 24 inches; beam, 12 inches. Total wing surface, 100 square inches.

Leonardo Da Vinci as Aviation Engineer

The Man Who First Suggested the Helicopter and the Motor to Drive Flying Machines

By Albert A. Hopkins

IN the March issue of the SCIENTIFIC AMERICAN MONTHLY we touched briefly upon the achievements of Leonardo as a scientist and inventor. There was one subject—aviation—which was left for fuller treatment. This was necessary because of the immense number of drawings and great amount of data which have come down to us.

The following presentation is timely for two reasons: first, the U. S. National Museum has just recreated a model of Leonardo's approved flying machine, and second, there has been great attention recently given to the helicopter of which we have incontestable proof that Leonardo was the real inventor, as will be shown in this article.

The writer wishes at this point to thank Mr. John W. Lieb for coöperation in allowing his magnificent collection of facsimilies of Leonardo's manuscripts, works on Leonardo and other data to be drawn on freely and all the illustrations are from this source except the National Museum model. His own writings are quoted freely in the article as are also the writings of Mr. Edward McCurdy who published a classic article on the subject in the *Nineteenth Century* a few years ago.

We do not know where Leonardo first obtained his idea of aerial flight, but we know he was occupied with the study of the exact workings of the forces of nature in every manifestation and of their application to human purposes. In the case of Leonardo, considered as the pioneer of the modern science of aviation, it is possible to define very narrowly the character of his researches and the nature of his conclusions. A sentence of Otto Lilienthal's, that great explorer in the realm of mechanical flight, who paid for his devotion with his life, expresses succinctly the measure of contempt which the practical inventor is apt to affect for the mere theorist however much he may be indebted to his researches: "To conceive of a flying machine is nothing, to construct one is something, but to make trial of it is everything." That Leonardo put his knowledge of theory to the proof is to be inferred from the only reference to these researches which is found in contemporary record. It occurs in the *De Subtilitate* of that somewhat empirical physician and philosopher, Jerome Cardan, who after including the invention of flight in a list of "the excellent arts which are hidden," continues: "It has turned out badly for the two who have recently made a trial of it: Leonardo da Vinci, of whom I have spoken, has attempted to fly, but he was not successful; he was a great painter." The laconic antithesis suggests—it almost summarizes—the attitude of contemporary criticism with regard to Leonardo's scientific and mechanical pursuits. The standpoint is the same as that of Vasari, who regarded them as deviations from those purposes which Leonardo alone could accomplish. The criticism has been justified by the march of events. One by one the mechanical and scientific problems to which a great part of Leonardo's creative power was devoted have been solved. He stands revealed as "the forerunner."

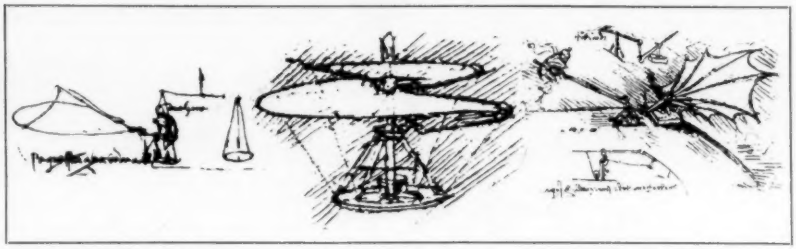
The researches on the science of flight which Leonardo's manuscripts contain are of themselves sufficient to reveal the unflagging zeal with which he devoted himself to the study of primary causes. The subject has given its name to one of the two of his treatises which exist in a more or less complete form (*Il Codice Sul Volo degli Uccelli*); but this would seem to be only an early draft of the results of his observations. It is also treated of in the *Codice Atlantico*, and in seven of the twelve Leonardo manuscripts which are now in Paris in the Library of the Institut de France. Some of these references consist of a few lines, or a diagram with a brief note in explanation, but many consist of pages or half-pages of closely written matter, the contents of which are far more voluminous than the writings of any other student of the subject down to Leonardo's time.

The material falls naturally into two groups, the first being a series of investigations of the laws which govern the power of flight as manifested in nature by birds and other winged creatures, the second consisting of deductions from these principles in the construction of a mechanism which should be capable of sustaining man and being worked by him. The interdependence of the two parts of the inquiry is stated with great succinctness in a passage in the *Codice Atlantico:*

"A bird is an instrument working according to mathematical law, which instrument it is within the capacity of man to reproduce with all its movements, but not with a corresponding degree of strength, though it is deficient only in the power of maintaining equilibrium. We may therefore say that such an instrument constructed by man is lacking in nothing except the life of the bird, and this life must needs be supplied from that of man.

"The life which resides in the bird's members will without

doubt better conform to their needs than will that of man which is separated from them, and especially in the almost imperceptible movements which preserve equilibrium. But since we see that the bird is equipped for many obvious varieties of movements, we are able from this experience to deduce that the rudimentary of these movements will be capable of being comprehended by man's understanding, and that he will to a great extent be able to provide against the destruction of that instrument of which he has himself become the living principle and the propeller."



SUGGESTIONS FOR WEIGHING WIND PRESSURE

HELICOPTER OR FLYING MACHINE FOR RISING VERTICALLY

MACHINE FOR TESTING WINGS OF VARIOUS SHAPES

Flight is a natural phenomenon, and consequently its laws are to be deduced by observation of nature. In acting on this principle Leonardo followed the course marked out by Aristotle in the chapters on the flight of birds in the treatise "On the Method of Progression of Animals," with which treatise it is at least reasonable to suppose him to have been somewhat acquainted.

References to Aristotle in his manuscripts are more numerous than to any other classical writer, and a note in the *Codice Atlantico* allows us to infer that he either possessed or had access to translations in manuscript or works which had not then been printed.

"In order (he says) to give the true science of the movement of birds in the air, it is necessary to give first the science of the winds, which we shall prove by means of the movements of the water: this science is in itself obvious to the senses; it will serve as a ladder to arrive at the knowledge of winged creatures in the air and the wind."

And again:

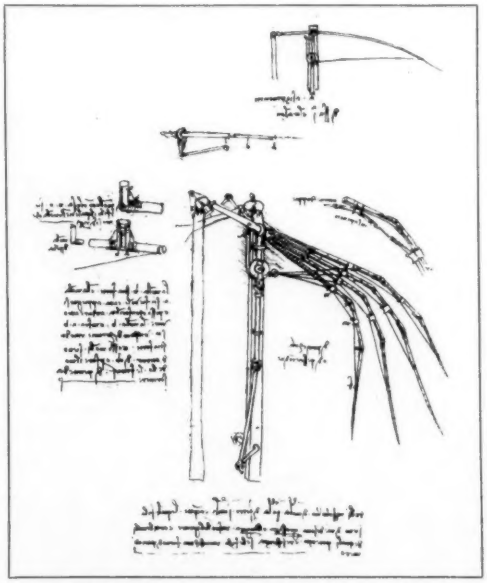
"Of the bird's movement—in order to speak of this subject it is necessary that in the first book you treat of the nature of the resistance of the air; in the second the anatomy of the bird and of its feathers; in the third the action of these feathers in various of its movements; in the fourth the strength of the wings and tail without beating the wings with the help of the wind to serve as guide in various movements."

And again:

"Before writing about winged creatures, make a book about how inanimate things descend through the air without wind, and another about their descent with the wind."

In treating of the science of the winds he shows how the wind varies in power according to its altitude, as is proved by the fact that birds always fly low when the course of the wind is contrary. The movement of the wind is similar in all respects to that of the water. The rudder behind the ship is copied from the tail of birds; and swimming upon the water teaches men how birds float on the air.

He also defines the resistance of the air, and shows how there is as much pressure exerted by a substance against the air as by the air against the substance; and he shows how the fact of a bird remaining motionless on its wings in the air is due to an equilibrium of forces; and he illustrates how the air beneath the movable substance which descends in it is compressed and the air above it is rarefied.



MECHANISM FOR A VERTICAL FLYING MACHINE, DRIVEN BY CRANKS WITH SUPPLEMENTARY WING FLEXURE OR WARPING

In his designs we find worked out in small detail, particularly as to the wings and mechanisms for operating and balancing, flying machines with two and four wings, operated by one or more persons with and without mechanical propelling power. We find some driven by spring motors, some by the arms and legs of the operator while lying prone or standing upright. We also find interesting sketches for a screw flying machine or helicopter and a sketch with descriptive details of a parachute.

In reading over the following extract and comparing it with the latest theories of airplane design, we cannot but feel that Leonardo was certainly well aware of the principles underlying aerial flight, in this detail if in no other.

"To Escape the Peril of Destruction When Flying.—The destruction of such instruments can happen in two ways, of which the first is that the instrument may break apart; the second would be if the instrument turned itself on edge or nearly on edge, because it should always descend on a very oblique path and nearly on a horizontal line."

We do not know today how many of Leonardo da Vinci's sketches and drawings were actually original designs or inventions, or how many were merely sketches to aid his memory of things he had seen. We do know that some small portion of the material given by Leonardo was not original with him, he having specifically mentioned that this or that device or idea was previously used by such and such a people or individual.

It would appear to Mr. Lieb, however, from a study of the manuscripts from an engineering standpoint, that so many of the sketches contain detailed calculations of weights, power required, etc., and so many others contain practical hints, which are really shop instructions for construction and operation, and that many of them could not have been the result of mere observation of apparatus constructed by others, but must have been the result of practical experiment and experience with actual apparatus under working conditions, supporting the contention that a very large part of the sketches are original designs and represent machines actually constructed by him or under his direction.

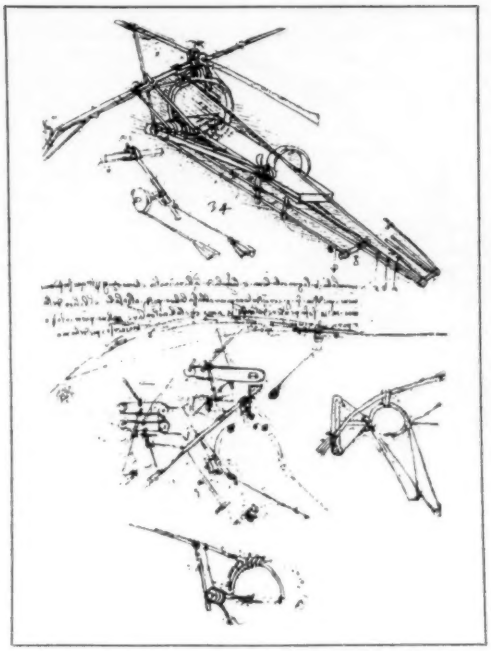
The first model of a flying machine took the form of a pair of large wings worked by means of the arms, or arms and legs, and attached to the body by a band which passed beneath the armpits.

The type in nature which Leonardo selected to serve as a model was the bat, "because its membranes serve as an armor,

or rather as a means of binding together the pieces of its armor, that is the framework of the wings." (*Sul Volo d. Uccelli.*) He admits that the wings of feathered creatures are more powerful in structure of bone and sinew, but attributes this to the fact that they are penetrable; that is, that the feathers are separated so that the air passes through them, whereas the bat is aided by its membrane, which is not penetrated by the air.

He has also shown that birds like the lark which fly high with the rising of their wings, because these are then pierced through with air, have their feathers spread out more widely than birds of prey which can only rise by a spiral or circular movement. He attempted, therefore, to combine both types by making the wing of the instrument like that of the lark as it rises and like that of the bat as it descends—or, as he calls it, "a method by which the wing is full of holes as it rises and closed up when it falls." This he did by attaching various shutters (*sportelli*) to the surface of the wing. A net connected the framework of the wing to the bamboo canes on which the shutters were fastened along their length on the one side, and on the other side were attached to them by cords at either end. The shutters had rims of cane and were covered over with taffeta, which had been either well soaped or rubbed with starch to render it airtight. As the wing rose the air would pass through the net, and force open the shutter to the extent allowed by the cords. As the wing descended the air below it would drive the shutter up against the net, and so close up the holes, and this would cause the wing to present a solid surface to the air beneath it. He considered that in proportion as the shutters were smaller so they were more useful.

In the second type the instrument has something of the appearance of the body of a huge dragon-fly, tapering slightly toward the tail, and the framework of the wings arched above the head resembles antennæ. Within the body the aeronaut lies at full length, face downward. His feet are in stirrups, which work the wings by means of cords, one of these causing them to fall and the other to rise. Round the neck is a leather band to which a cord is attached, described as "a rudder which is fixed with a band to the head at the place of the neck." The position of the instrument he states to be such that the wings in descending drop partly downward and partly backward, that is toward the feet of the man. The necessity of increasing the power of control led him so to change the mechanism that the wings were lowered by the force of both feet at one and the same time. By this means the downward pressure becomes twice as great and "you are able to delay and to maintain yourself in equilibrium by lowering one wing more rapidly than the other, according to necessity, as you see done by the kite and other birds."



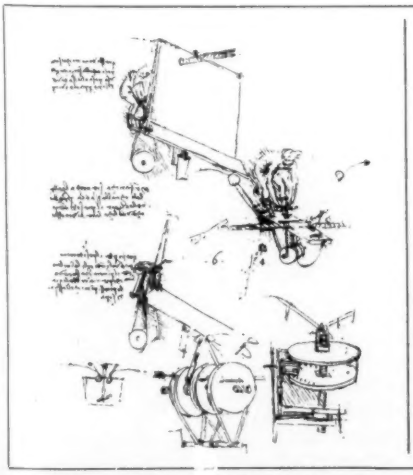
FLYING MACHINE USING ARMS AND LEGS, OPERATOR LYING PRONE, MANEUVERING TAIL BY OPERATOR'S HEAD

The raising of the wings will then, he says, either be by the force of a spring, or by the hand, or by drawing the feet toward you, the last being the best method, because then the hands are left free.

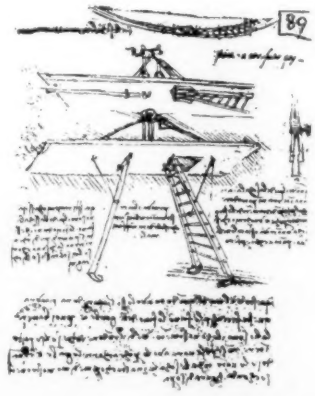
In a passage in the *Sul Volo degli Uccelli* he says that a man in a flying machine should be free from the waist downward to be able to balance as in a boat, so that his center of gravity may balance that of the machine.

With the various drawings of instruments are notes as to the materials of which the parts are to be constructed. Sometimes a word or more is written in the particular part itself, such as "staff of green pine," "fustian," "taffeta," "try first with leaves of chancery," which latter may be interpreted to mean a form of parchment. Two parts of the covering of a wing are described, one as of "fustian stuck over with feathers," the other of "starched taffeta," and "for the experiment," he continues, "you will use fine pasteboard."

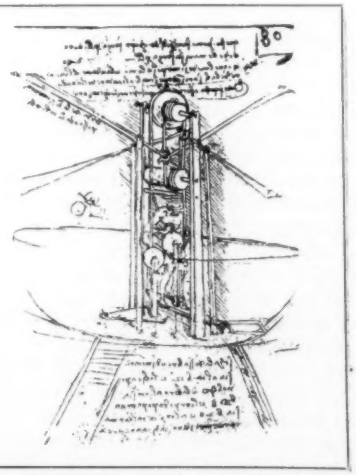
The same forethought prompts a note that the machine should be tried over a lake, and that a long leather bottle



SKETCHES GIVING DETAILS OF THE MANUALLY OPERATED MECHANISM OF THE FLYING MACHINE



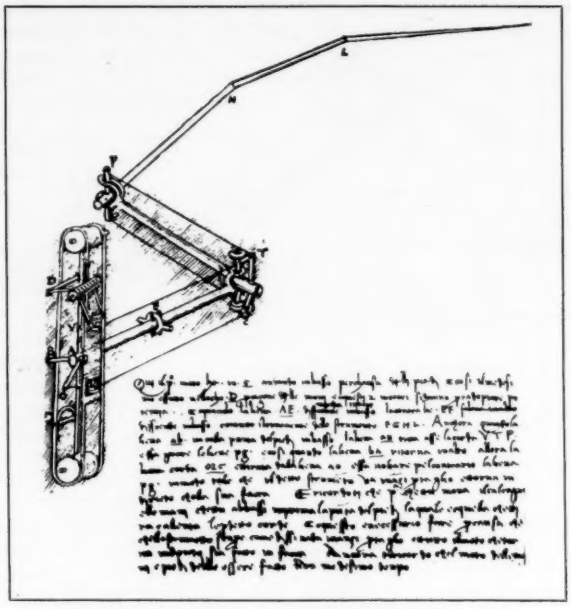
FOLDING LADDER WITH SHOCK ABSORBER FOR LANDING, SHOWING COLLAPSIBLE MECHANISM



A FOUR-WING FLYING MACHINE. OPERATOR STANDING, WITH HEMISPHERICAL BASE AND LANDING

should be carried in the girdle as a safeguard against drowning in case of a fall; and again, in writing of another type of machine, he says: "Try the actual instrument in the water so that if you fall you will not do yourself any harm."

The various notes and drawings which relate to what was probably the latest type of the machine are among the most difficult to interpret. The machinery, although more compact, has become more complicated, and an attempt to define the practical value of the parts of it is only possible to the practised student of mechanics. A drawing of a man suspended by the waist, in an attitude as though swimming immediately below the drum round which the cord is turned, is apparently a preliminary to this latest type: the note below it describes how it may be worked either with one pair of wings or with two, and refers to a ladder or ladders of light thin pine at the base. These ladders are found only in the latest type of the instrument, and he defines their use as serving the purpose of legs when it is desired to rise above a plain, and so rendering it possible to beat the wings. He mentions the instance of the martin, which cannot raise itself by flying when settled on the ground, because it has short legs. A drawing shows how, after the ascent had been commenced, the ladders are to be drawn up so that they lie flat against the bottom of the instrument. They are made with curved ends in order, apparently, to lessen the risk of their becoming fixed in the ground.

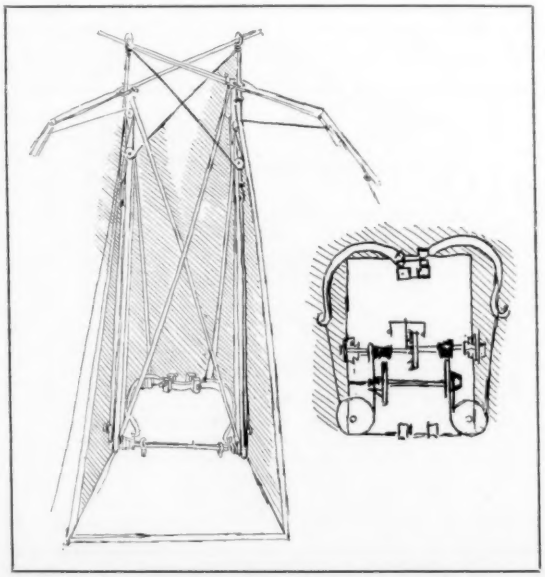


DRIVING AND FLEXING MECHANISM FOR WINGS, WITH UNIVERSAL JOINT

"I conclude (he says) that standing upright is more useful than flat on one's face, because the machine can never turn upside down, and moreover the habit created by long use requires it thus. And the rising and falling of the movement will proceed from the lowering and raising of the two legs, and this is of great force, and the hands remain free, and if one had to be flat on one's face the legs in the fastenings of the thighs would have great difficulty in supporting themselves; and the feet have the first shock when it alights."

A drawing in MS. B of the Institute is the most complete representation of this type of the instrument. In it the figure of the man is seen standing on his feet, but bowed like Atlas under his burden.

Above him are two pairs of wings, which are worked by cords and pulleys controlled by his head and limbs. He is placed between two posts, which support a wheel at the top. Cords passed round it raise and lower the wings as the wheel moves. The posts descend to the base of a low basket-shaped car, where are pedals on which the man stands. These pedals are connected by cords with the wings. The car is resting on short ladders.



A REAL "AIRPLANE," SHOWING IN DETAIL, MECHANISM OF SPRING MOTOR "FONDAMENTO DEL MOTO"

On a page of MS. B of the Institute is a drawing of a large screw constructed to revolve round a vertical axis. The notes at the side and below the drawing tell of the materials and dimensions, and reveal also the purpose which it was intended to serve.

In its general outline this instrument has some resemblance to certain examples of the type known as helicopters. But both in this and in the earlier model, of which the general structure has somewhat more resemblance to certain types of the modern airplane, the only motive power to be discerned is derived directly from the strength of the human agent. The capacity of the instrument to overcome the resistance of the air is the capacity of his muscles to lift weights and to endure pressure, transferred to this particular purpose by the use of suitable implements. Numerous passages in the manuscripts show that Leonardo doubted the adequacy of this power to accomplish more than short experimental flights. He contrasted it with that reserve of power possessed by the larger birds, and he sought for a fresh source of motive power to supplement or take the place of that exerted by man.

M. Govi, who first called attention to the significance of these passages in a paper presented to the French Academie des Sciences, speaks of them as proving not only that Leonardo invented the screw-propeller, but that he had considered its application to aerial navigation, and that he had constructed small paper models for this purpose which were set in motion by fine bent steel wires.

The function of springs in the machinery of some of the flying machines is shown in two important drawings of a flying machine on a page of the *Codice Atlantico*. These show a machine of the vertical type with a planimetric sketch of the base, within which is written *fondamento del moto*. These, together with an elaborate study of the mechanism of the right wing represent the ultimate stage of the conception as found in the manuscripts —which stage is separated from those which preceded it by the addition of mechanical motive power. To this instrument the architect, Luca Beltrami, does not hesitate to apply the word "aeroplane."

"The apparatus consists of a rectangular horizontal plane, from the middle of the longer sides of which rise two vertical struts made firm by two sup-

ports crossed diagonally. The vertical plane so formed is made rigid by two pairs of supports which connect the upper extremities of the struts with the angles of the plane of the base. Two strong springs, each fastened at one end to the center of one of the lesser sides of the horizontal plane, are bent round its sides by means of ropes, which by the interposition of pulleys are made to turn round a horizontal axle placed at the base of the two shafts; a cog-wheel situated in the center of this axle allows the force stored up in the springs in tension to be able gradually to relax the rope, so causing the revolution of a second axle parallel to the first, and at the extremities of this are cranks for the purpose of moving the wings. These wings are poised at the upper extremities of the shafts, the right wing being fixed upon the left shaft and *vice versa*, so that the space between the two shafts, along which the motive power is exerted, forms the arm of a lever of which this power may avail itself." Each wing is moved by a vertical rod which is looped to the shaft by two rings, and gliding through these it may be raised and lowered according as the fastening to one of the above-mentioned cranks is loose or tight. The lowering of the rod not only moves the arm of the lever, of which the wing is a continuation, but displaces a pulley which turns the cords that correspond to the various loose sinews, which together make up the subsidiary structure of the wing: consequently, as the wing is raised and lowered, these sinews and the surface of the wing are expanded and contracted.

All this relates to constructional details of the instrument. Signor Beltrami, in a few sure words, shows how these parts would be controlled by the human agent:

"The man who guided the machine had his place in the part of the horizontal plane enclosed within the two springs where the words *fondamento del moto* (foundation of the motor) occur in the sketch. He had the cog-wheel in front of him, and could by a simple turn so adjust its revolution as to allow the ropes pressed by the springs to relax gradually and at his pleasure, and so cause the revolution of the axle where are the two cranks which communicate with the wings: as the slackening of the rope is quicker or slower, so the beating of the wings is more or less rapid, and so the flight is controlled."

If Leonardo did not enter the Promised Land, here, surely, he had a Pisgah-sight of it! In arriving at this stage he was separated from that of ultimate attainment only by the lack of knowledge of a light motor with power sufficient to move the mechanism, such as has only been rendered possible by the use of the explosive engine.

An enigmatic sentence on the cover of *Sul Volo degli Uccelli* which was written in 1505, refers apparently to an attempt at flying which was then shortly to take place:

"The great bird will take its first flight upon the back of the Great Swan* filling the whole world with amazement, and filling all records with its fame; and it will bring eternal glory to the nest where it was born."

*This refers evidently to a mountain near Florence which was known as the "Swan."

"The Automatic Pilot"*

New Airplane Stabilizer That Is Part Electric, Part Pneumatic and Part Aerodynamic

WHILE it must be admitted that the number of aviation accidents directly due to failure on the part of the pilot is extremely small, it is none the less desirable that any means provided to lessen the possibility of such failures should be considered on its merits. A short airplane flight, carried out in normal circumstances, is not a particularly fatiguing operation so far as the pilot is concerned, but a prolonged journey in gusty or misty weather subjects him to a degree of mental and physical strain which it is certainly desirable to avoid by mechanical appliances if possible. We have recently had an opportunity of examining a device, the invention of M. Georges Aveline, which has been fitted to a Handley-Page passenger airplane and is capable of relieving the pilot of the whole work of balancing the machine except during the operations of getting off and landing. The pilot, for practically the whole of the journey, need thus only keep his feet on the rudder bar in order to keep the machine on the correct compass course set, the ailerons and elevator being operated by the apparatus which we propose to describe.

Fig. 1, on the next page, indicates the principle of that part of the apparatus which controls the ailerons, and is mounted transversely in the cockpit or other convenient part of the airplane. The essential part of this device is a disc of red fiber in which a circular channel is formed, the channel being about half filled with mercury. Just above the surfaces of the mercury in the channel an electrical contact is fitted on each side of the disc, and another contact is made with the mercury at the lowest part of the channel; if the machine tilts laterally on either side the circuit between the lowest contact and the contact on that side will thus be completed through the mercury. The upper contacts of the mercury channel are connected to the two coils of a relay and when the circuit is completed through one of the contacts, this relay closes a 12-volt circuit in which are the solenoids controlling the inlet and exhaust valves of a servo-motor worked by compressed air. This servo-motor, as shown in Fig. 1, contains two opposed pistons connected by a rack, and the rack gears with a quadrant connected to the aileron control wires. When air is admitted to one end of the servo-motor and the exhaust valve at the other end is opened, the pistons move, turn the quadrant, and so operate the ailerons to correct the tilt. As shown in Fig. 1, the disc containing the mercury channel is also geared to the quadrant, so that it turns in the opposite direction and, by this means, the contact is broken and the pistons brought to rest after moving a distance corresponding to the amount of tilt. It should also be explained that the rate of movement can be regulated as desired by means of a valve fitted in the exhaust pipes.

An interesting feature of M. Aveline's invention is the means adopted to counteract the effects of centrifugal force, but to understand the effect of this part of the apparatus it is necessary to consider its action during a turn. To turn the machine, the pilot moves the rudder bar with his foot, and the machine immediately commences to swing round in a more or less horizontal plane—say to the right. The resulting centrifugal force causes the mercury to rise in the left-hand arm of the mercury channel making a contact on that side, and the effect of this is to pull down the outer aileron and raise the inner aileron, thus causing the machine to bank in the correct manner. The fiber disc, of course, moves in the opposite direction to the quadrant and would break the electrical connection and leave the ailerons in the positions above described but for the special device we shall refer to in a moment. It must, however, first be explained that, as soon as the correct banking is reached, it is necessary to replace the ailerons into the neutral position, otherwise the banking would become excessive and the machine would probably side slip. To avoid this, the arrangement illustrated diagrammatically in Fig. 2 is employed. A Venturi tube is mounted on each tip of the upper wing of the machine and the throats

*Reprinted from *Engineering* (London), Feb. 11, 1921.

of the tubes are cross-connected to the arms of the mercury tube as indicated in the diagram. It will be obvious that the suction from the Venturi tube on the outer wing tip will be greater than that from the other tube since the former is moving faster than the latter, and the effect of this will be to raise the mercury in the inner arm and make an electrical contact on that side. By this means the ailerons are returned to the mid position, and the machine continues to travel on a properly banked turn until the rudder bar is again moved by the pilot, when the reverse action takes place, bringing the machine back to a horizontal straight-line path.

The apparatus for controlling the elevator is generally similar in principle to that used in connection with the ailerons, the main distinctions being that the plane of the mercury channel is mounted in a fore and aft direction and that one arm of the mercury tube is connected to a Venturi tube in the center of the machine, while the other arm is open to the atmosphere. The arrangement of this part of the apparatus is indicated by the diagram, Fig. 3. In normal flight the position of the mercury would be as shown in the illustration, the forward arm being at a higher level than the after arm owing to the suction of the Venturi tube. The pilot has to adjust the fiber disc so that the electrical contacts are just above the level of the surfaces of the mercury in the arms and any alteration in the speed, or fore and aft inclination, of the machine will then complete the circuit to a relay and servo-motor similar to that already described, thus effecting the necessary adjustment of the elevator. It is equally possible for the pilot to set the disc for any desired angle of climb and the machine will then continue to climb at this angle until the disc is readjusted for horizontal flight. In the event of engine failure while the fore and aft automatic control is in use, the drop in speed and the consequent diminution in the suction from the Venturi tube, will allow the mercury to fall in the right-hand arm of Fig. 3 and rise in the left-hand arm. In this way the servo-motor will be operated to put the machine into a downward glide without any action on the part of the pilot, who would only have to steer the machine to a possible landing ground and flatten it out just before alighting.

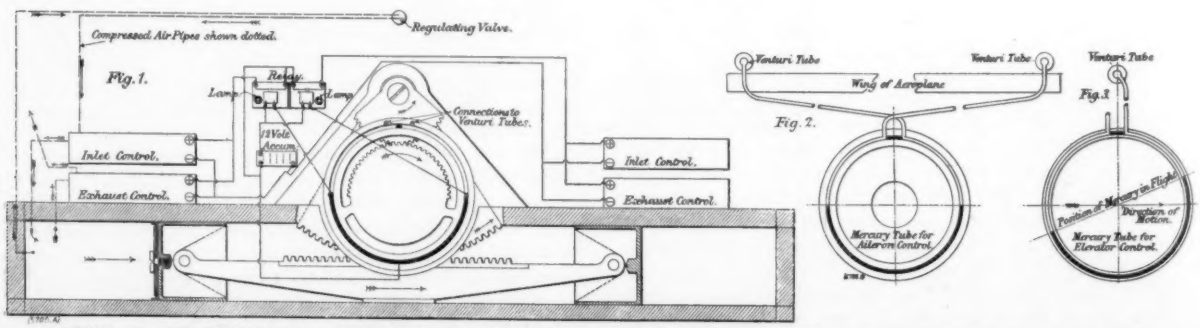
If it is desired to control the machine in the ordinary way, either or both the servo-motors can be instantly put out of action by the pilot, without leaving his seat, by means of valves fitted in the compressed-air pipes or by slackening the cables connecting the quadrants with the main control cables. If the former method of disconnection is adopted the apparatus can still be employed as an inclinometer to indicate a tilt in either the longitudinal or lateral directions. This is due to the fact that small incandescent lamps are included in the circuits connecting the mercury channels with the relays. The lamps are fitted in the front of the relay casings, which are mounted on the instrument board in the cockpit in full view of the pilot. When the machine is flying level laterally, or at the correct longitudinal inclination, all the lamps are extinguished, but a slight tilt in either direction, by disturbing the level of the mercury, will cause one or other of the lamps to light up and indicate the existence of the tilt to the pilot.

The compressed air required to operate the servo-motors is provided by two small wind-driven rotary pumps mounted on the bottom longerons on both sides of the fuselage. These pumps maintain a pressure of about 60 pounds per square inch in a cylindrical reservoir placed inside the fuselage. The reservoir also serves as a receptacle for oil for the rotary pumps, these, of course, requiring constant lubrication. A maximum pull of 500 pounds can be produced in the cable attached to the quadrant, this pull being ample for the control of the largest machines at present in use.

The principal objection to the use of apparatus of this kind is, of course, its weight, since the maximum paying load must necessarily be reduced to some extent. The actual weight of the complete installation on the Handley-Page machine above referred to, amounts, we are informed, to 150 pounds, which is about equal to the weight of one passenger. This, however, is hardly so serious as appears at first sight, since the passenger-carrying capacity of a large machine is usually limited more by considerations of space than of weight, and, moreover, it is an unfortunate fact that the machines are rarely loaded to their full passenger-carrying capacity. Another point in favor of the apparatus is that its use would probably avoid the necessity for employing an assistant pilot on a long journey with a large machine, and this fact would more than compensate for the weight of the apparatus. It should also be mentioned that, in later designs, the inventor expects to reduce the weight of an apparatus of equal capacity to about 100 pounds, and a device designed for use on small two-seater or three-seater machines weighs only 20 pounds. In this, however, the use of compressed air is avoided, the servo-motor being replaced by an ingenious friction gear driven by a small windmill. The invention appears to us to be especially useful in flying through clouds, as well as in night flying, and the fact that the Air Ministry, after extensive trials, have had it fitted on 12 Handley-Page bombing machines for the Royal Air Force, indicates that they are satisfied as to its practicability.

A DEVICE FOR MEASURING THE INTERNAL DIAMETER OF GLASS TUBING

THE instrument consists of a thin-walled brass tube inside which a rod carrying a cone at its lower end slides. At the bottom of the tube is a brass ring carrying three wires stretching upward, with a phosphor bronze ball at the end of each wire, suitable holes and slits being provided in the sides of the tube to allow free play to the balls and wires. When the instrument is placed inside the neck of a flask the rod is pushed down until the cone at the end of it can descend no further owing to the balls being pressed against the inside of the flask neck, when the diameter can be read off from the scale engraved on the top of the rod.—Abstracted by *The Technical Review* from *Journal of the Society of Glass Technology*, Oct., 1920.



FIGS. 1-3. DIAGRAMS ILLUSTRATING THE OPERATION OF THE AVELINE AUTOMATIC STABILIZER FOR AIRPLANES

The Nature of Vowel Sounds*

The Laryngeal Puff Which Distinguishes the Musical from the Unmusical Quality of Voice

By Prof. E. W. Scripture

SINCE the time of Wheatstone and Helmholtz the vowels have been almost universally supposed to obtain their tones by acting as resonators to certain overtones of the larynx tone. Helmholtz even constructed an apparatus of a set of harmonic tuning-forks by combinations of which he hoped to produce the vowels. Ever since the invention of the speech-recording machine by Scott and Koenig in Paris the analysis of vowel curves has been expected to solve the problems of the nature of a vowel and of the differences between different vowels.

At the present day the vowels can be recorded on talking machines, and their curves can be traced off with an accuracy that leaves nothing to be desired. The work of Hermann on

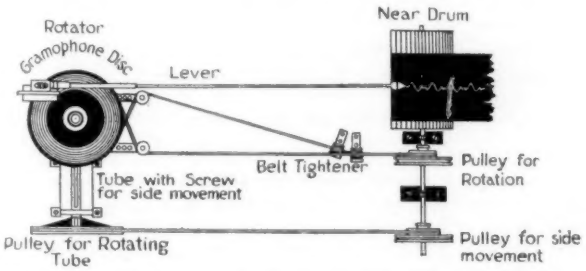


FIG. 1. APPARATUS FOR TRACING GRAMOPHONE CURVES.

A steel needle near one end of a long lever follows the groove. Its movements are enlarged 500 times and registered on a band of smoked paper.

the curves of the vowels and consonants by means of the phonograph is still unsurpassed. For my own investigations the gramophone was chosen as the most available machine.

A disc with the desired record was placed on a very slowly revolving plate (Fig. 1). A long lever of Japanese straw was held in an axle at one end. Near this end a steel point projected downward into the speech groove. At the other end there was a recording point made of a fine glass thread. As the disc revolved, the movements were magnified—up to 500 times—and traced on a moving band of smoked paper.

Pieces of vowel curves cut out of a tracing of a record by Joseph Jefferson are shown in Fig. 2. The curves show that in speech the vowels change constantly in pitch, in intensity, and in character. They also show that the vowels actually used in speaking are often not what the phonetician supposes them to be.

The point of interest on the present occasion, however, is the nature of a single wave of a vowel. At the present day there is only one way of analyzing a wave—namely, the harmonic analysis. Any wave can be represented as made up of a series of simple sine waves with the relations of frequency of 1:2:3: . . . and with various amplitudes. A harmonic analysis of the wave in the top line of Fig. 3 gives the four curves in the lines below. This means that the four curves, if added together, will give a result like that in the top line.

Suppose, now, that we have a curve that consists of a vibration repeating itself every 3½ times to a wave. The harmonic analysis gives as result a fairly strong fundamental of the frequency 1, a stronger vibration of the frequency 2, a still stronger vibration of the frequency 3, a somewhat less strong vibration of the frequency 4, and ever-lessening vibrations of the frequencies 5, 6, 7, etc. Not one of these vibrations was actually present in the original curve. The strength of the original vibration of 3½ could not be directly given, because there was no place for it in the harmonic series.

The harmonic analysis shows us how a given curve can be represented as made up of a series of harmonic components; it does not say that it was originally so produced. Such a deduction has to be made on other grounds. The familiar experiment with a piano string touched lightly in the middle, then at one-third of its length, etc., shows that it vibrates in harmonic parts; an analysis that gives the harmonic components in various amplitudes can be accepted at once as indicating the strength of the components. An analysis, however, that gives all the harmonics as being present to some degree with a bunch of strong ones at one or more points would indicate at once that one or more inharmonics were present.

A harmonic analysis of the wave in Fig. 4 from the first vowel in "Marshall" gives the harmonic plot shown in Fig. 5. This merely states that the original wave can be reproduced by using harmonics in the relations indicated. The deduction concerning how the wave was originally produced is left for the person who interprets the harmonic plot.

If such a result were obtained for a wave from a musical orchestra, we should have no hesitation in concluding that the wave was produced by a summation of vibrations in the harmonic relation. If the wave originated from a single source, we should certainly not be justified in drawing the same conclusion without further evidence. In seeking for further evidence we find, in the first place, that the waves

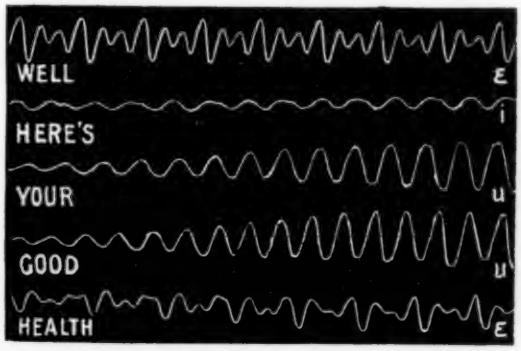


FIG. 2. VOWEL CURVES. THE WAVES FALL INTO GROUPS.

The top line contains eight groups, the next line six, the third seven, the fourth eight, and the last seven. Each group corresponds to one vibration from the larynx. The length of a group gives the pitch of the laryngeal tone; in speech this is always rising or falling. The height of the waves indicates the intensity. This is nearly always small at the beginning of a vowel; there is a steady rise to a maximum and then usually a fall to the end. The small waves within a group give the characteristics of the vowel sound. The top line is a piece out of the middle of the vowel in "well." The second line is from the vowel in "here." The third is near the beginning of "your." The fourth is the first part of the vowel in "good." The last is from the middle of "health." In the second, third, and fourth cases there is evidently present a tone more or less nearly the octave of the laryngeal tone. The other tones and the tones in the other cases can be found only by analysis.

from musical instruments so far as yet studied—the material is extremely limited—do not give harmonic plots like that in Fig. 5, and do give plots having one, two, or three prominent harmonics with the others lacking. This would agree with the known fact that most musical instruments vibrate in harmonics. If the source of the wave were absolutely unknown, the most plausible deduction would be that it was some body or bodies that might vibrate in either harmonics or inhar-

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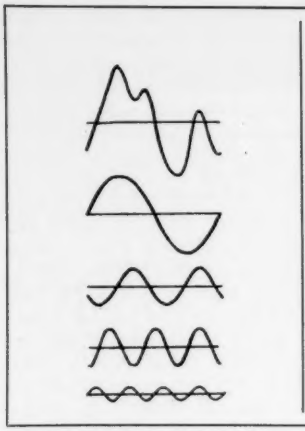


FIG. 3. A CURVE COMPOSED OF FOUR SINUSOIDS

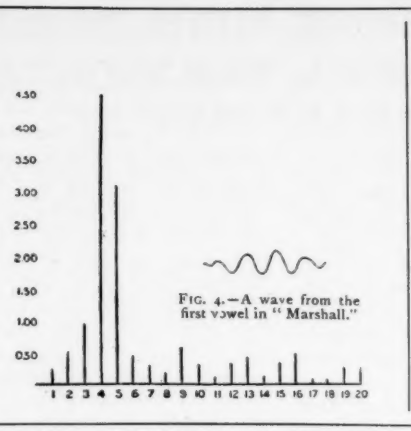


FIG. 5. RELATIVE AMPLITUDES OF SINUSOIDS FOUND BY HARMONIC ANALYSIS

FIG. 4.—A wave from the first vowel in "Marshall."

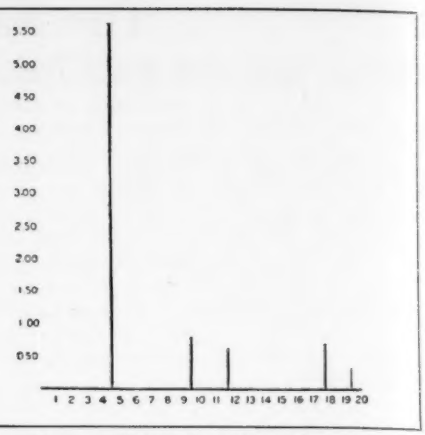


FIG. 6. RELATIVE AMPLITUDES OF COMPONENT INHARMONICS DEDUCED FROM FIG. 5

monics. We should take the weighted means of the groups of strong harmonics, and should find in this case that the components were the inharmonics

1 :4.3 :9.3 :11.5 :17.6 :19.5.

The result can be expressed in the inharmonic plot in Fig. 6. This conclusion is of vital importance, because such results are just those that are always obtained from careful vowel analyses. The very harmonic analysis itself leads to the conclusion that the vowel tones may be inharmonic.

In the analyses of vowel waves the fundamental is indicated as weak (as in Fig. 5) or often almost lacking. This fundamental represents the voice tone or the tone from the larynx. We all know that this is the strongest tone of all. We may not be able to hear just what vowel a speaker or singer is producing, but we certainly know whether he is using a high or a low tone of voice. One writer, observing this peculiarity in the analysis of the waves obtained from a phonograph, remarked that this instrument must be deaf to the voice tone. He failed to consider that if it was deaf to this tone it could not reproduce it, and that even the most defective phonograph will produce the voice tone so long as it makes any noise at all. The weakness of the fundamental in Fig. 5, therefore, does not show that the fundamental was lacking in the original vibration.

Let us inquire what kind of a strong tone will appear in the harmonic analysis with a weak fundamental. This is the case with a series of sharp puffs. If the period from one puff to the next of a series is subjected to harmonic analysis, the result shows a weak fundamental with all the higher harmonics represented in ever-diminishing amplitudes. The fundamentals in the vowel curves are therefore not of the nature of sine vibrations, but of series of more or less sharp puffs.

This is not a new theory of the vowels. In 1830 Willis published, in the Transactions of the Cambridge Philosophical Society, a paper on the tones of the vowels and reed organ-pipes. He asserted that a vowel was composed of a series of puffs with a set of inharmonic overtones. This was rejected in favor of the harmonic theory by Wheatstone, whose conclusions were accepted and developed by Helmholtz. For nearly a century the harmonic theory has been universally accepted. In a series of researches beginning in 1889 Hermann found that the analyses of phonograph curves showed the vowels to be constructed of puffs and inharmonics. He thus independently rediscovered the principle of Willis. This theory has been substantiated and developed by thousands of analyses in my work for the Carnegie Institution of Washington, and published in *The Study of Speech Curves* (Carnegie Inst. Publ. No. 44), from which the above results are taken. It should be added that this extensive and somewhat expensive work was made possible by the support of Yale University and the liberality of the Carnegie Institution of Washington.

THE MANUFACTURE OF VOWELS

For the manufacture of vowels Helmholtz used tuning-forks that gave smooth vibrations and not puffs; moreover, the only overtones tried were harmonic to the fundamental. Some years ago I made an attempt to manufacture vowels on the principles discovered by the analysis of vowel curves.

The fundamental was produced by a puff siren (Fig. 7) similar to the familiar one of Seebeck. As a slit passes across the blast tube a jet of air issues for an instant. This is heard as a faint puff. As the disc is rotated more rapidly the puffs come oftener, until at one region a low tone appears. With still greater rapidity the pitch of the tone rises.

When a brass resonator is placed in front of the tube of the siren it sounds loudly when the frequency of the puffs is the same as that of the tone of the resonator, and also less loudly when it is in some other harmonic relation. For inharmonic relations the resonator is silent. Resonators with hard walls, therefore, cannot be used to produce sounds containing inharmonic components.

The soft-walled resonators of the mouth can be imitated by spreading pieces of meat over wire frames. As this has its inconveniences, a wire frame may be covered with a layer of absorbent cotton soaked in water. Such a resonator is shown in Fig. 7. The walls are quite inelastic. When such a water resonator is placed in front of the tube of the siren, it responds equally well to all tones of the siren, whether harmonic or inharmonic. Two or more resonators can be combined to meet the requirements for various vowels.

The theory of this vowel siren can be illustrated by the diagrams in Fig. 8. The puffs come as sharp blows almost instantaneous in character; they are indicated by the crosses. When such a blow strikes a resonator with soft walls, it arouses a vibration in the cavity that dies away very rapidly, as is indicated in the first line of the figure. The vibration is entirely gone before the next puff hits it. The response of the resonator is quite independent of the frequency of the puff. When, however, a puff strikes a resonator with hard walls, it arouses a vibration that dies away very slowly. When the next puff comes, the result depends on its relation to the vibration still going on in the cavity. If the puff hits the resonator at a moment when its frequency would be a submultiple of the frequency of the resonator, then it will reinforce the vibration and make the resonator tone louder. This is illustrated in the second line of the figure. If, on the other hand, it hits the resonator at a moment one-half a period short of a harmonic relation, it will kill the vibration it finds. A very weak tone may be aroused by puffs with a

frequency that is not a sub-multiple of the frequency of the resonator, but no strong response can be obtained outside the harmonic relation.

The siren with water resonators was constructed with the aid of Hodgkins fund of the Smithsonian Institution of Washington. It produced most of the typical vowels with success. Under the Carnegie Institution the work was continued with an attempt to imitate more closely the conditions in the living body. Although the cheeks can be represented by water resonators, the roof of the tongue is somewhat more difficult; the roof of the mouth is quite an approach to a hard resonator. To imitate these conditions, a resonator was made of a skull supplied with cheeks and a tongue of gelatine. The tongue was removable, so that models of different forms could be inserted. The voice tone was obtained from a vox humana organ-pipe. The ultimate object was to find vowel resonators that would respond with specific vowels to any tone. These were then to be mounted on a reed organ as an extra register. All tones issuing from the organ could be made to pass through one of the vowel cavities, and the organ would thus sing the vowels. In most singing the consonants are a subordinate matter, and such an organ would aid the singing of a choir or a congregation. The beauty of such a vowel register in a large organ in a cathedral is quite beyond imagination. This investigation was also supported by the Hodgkins fund, but was discontinued on account of the work required for the study of speech curves.

THE STRUCTURE OF VOWELS

The study of speech curves and the making of vowel-producing instruments show that two groups of elements are to be found in a vowel.

The first is the voice tone. Three properties of this tone are to be considered. The pitch of the tone is given by the rapidity with which the laryngeal puffs are repeated. If V indicates the number of puffs per second, then $V = f(t)$ is the general expression of the fact that the pitch of the voice tone depends on the elapsed time. It might be supposed that, in singing a vowel on a given note, the pitch would remain constant. A study of a record by the tenor Caruso (not yet published) shows that he never keeps his voice on a constant pitch during a vowel, but makes continual small changes. A study of the vowel "oh" used as an interjection shows that the pitch of the voice tone changes to express the emotion and the meaning of the interjection according as it is spoken to express sadness, admiration, or doubt. In fact, it is quite possible to obtain an equation for V for each of the three cases. In ordinary speech the pitch of the voice tone changes from instant to instant. Every individual vowel has a melody of its own. This melody varies with the emotion, the meaning, and possibly other factors.

The intensity of the voice tone depends on the energy of the puffs from the larynx. If I indicates the puff energy, then $I = f(t)$ expresses the fact that the intensity varies from moment to moment. The speech curves show changes of intensity that express emotion and meaning. Even in song—as Caruso's curves show—the intensity is constantly varied in a way that makes his song a production of art, and not a mechanical performance.

The third factor of this group is the musical character of the voice tone. This depends on the *shape* of the puff from the larynx. The matter is of such importance that the following statement seems to be needed.

After a tuning-fork has been struck its vibrations slowly die away. Its curve is really not that of a simple sinusoid, but that of a frictional sinusoid

$$y = a.\ e^{-\varepsilon t}\frac{2\pi}{T}t, \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

where y is the elongation at the moment t, a the amplitude or maximum elongation, T the period, e the basis of the natural system of logarithms, and ε the factor of friction or damping. The period T is affected by the factor of friction, but the amount is so small that it can be neglected here. The effect is to cause a decrease in the amplitude. When the value of ε is great, the curve is that of a sharp puff. When it is less, the puff is more gentle. If it were o, the ordinary simple sinusoid would be obtained.

The puff from the larynx may be of a complicated form that should be represented by the sum of a series of frictional sinusoids. The complete equation would be

$$y = \Sigma a.\ e^{-\varepsilon t}\ sin\ \frac{2\pi}{T}\ t. \quad \ldots\ldots\ldots (2)$$

This comprises the whole of the vibration of a single puff. It is a free, and not a forced, vibration. The musical or unmusical quality of the voice depends solely on the presence or absence of the various members of (2). The quality of the voice that distinguishes a Caruso from a costermonger lies exclusively in the laryngeal puff. This fact is of importance as contradicting the almost universally accepted theory of vocal training that is based on "tone-placing" by the supposed action of the vocal cavities as resonators to give the musical quality to the tone from the larynx.

The other group of elements comprises the tones aroused in the vocal cavities. A puff striking a cavity arouses one or more vibrations of the form of a frictional sinusoid as in (1). Each cavity will have its own factor of friction and its own period. As shown by the vowel siren, this response will be a free vibration independent of the voice tone and the periods that go to the vibration that makes up the puff. Every change in the sizes or openings of the cavities will alter the periods of these vibrations. The possible combinations for the cavities of the chest, pharynx, mouth, and nose provide for an almost endless variety of vowels.

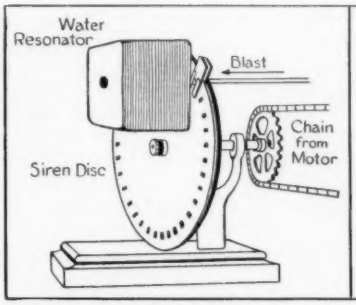


FIG. 7. PUFF SIREN WITH WATER RESONATOR

FIG. 8. VIBRATIONS IN RESPONSE TO PUFFS

The puffs are indicated by the crosses. The first line shows the response of resonator with soft walls. In the second line the puffs hit a resonator with hard walls in such a way as to maintain strong vibrations. In the third line the puffs hit the same resonator in a way to produce little or no effect.

The speech curves show quite unexpectedly that there is no such thing as a constant vowel. The vowel "o" in "so" changes its specific vowel character from beginning to end. The least change is found in German; more change appears in American. There is so much change in English that an American hears the vowel "o" as a sound starting like "oh" and ending like "oo." The statement that this English vowel is a diphthong composed of two vowels is incorrect. The vowel is a single sound that gradually changes greatly in character. There is no objection to calling it a diphthong provided it be recognized—as the speech curves show—that all diphthongs are really single vowels that change greatly in character. At the same time, it must be recognized that what is called a single vowel may change even more in character than a so-called diphthong; the change in a very short vowel, as in "but," is often surprising.

Just what constitutes the differences between the different vowels is a problem at present beyond the reach of science. The ear tells us that there are many sounds which we group

together under the type "ah"; many others that would go to form the type "oo," etc. The speech curves show that the multiplicity of varieties under each type is almost beyond belief. In a general way we know that the impression from "ah" is that of a higher tone than from "oo," from "ee" higher than from "ah," and so on. All details of the tones in a single vowel are lacking. Every investigator has differed from every other one in regard to what tones constitute any particular vowel. As shown in this article, we can get so far as to say on what principles a vowel is built up. We can even get curves of the vowels of an accuracy that leaves nothing to be desired. We have not, however, any method of analyzing these curves accurately into a series of frictional sinusoids with independent periods and factors of friction. We must probably wait for some mathematician to do for this problem what Fourier did for harmonic motion.

DUPLICATING THE CUBE—ALMOST

EVERY little while we are called upon to pass on the work of somebody who thinks he has resolved the problem of squaring the circle, of duplicating the cube, or of trisecting the angle. These claims fall into two distinct groups. There is the man who has a construction that will really do what he thinks it will, but which is not itself a Euclidean construction. Nobody, we suppose, would claim to have squared the circle by rolling it through a complete revolution and measuring the line thus generated; yet cubes are duplicated and especially angles are trisected by stunts that are equally wide of the recognized rules of the game, and the perpetrators of these stunts demand recognition as having put to shame the integrated mathematical ability of twenty centuries.

Then there is the man who has a construction that he can really carry out with compass and ungraduated straight edge, and which comes so close to a numerically exact trisection or duplication or evaluation of *pi* that he mistakes approximation for achievement and claims to have solved the age-old riddle. Some of these demonstrations are marvels of draftsmanship, being the fruit of a figure so complicated that it is only with the greatest difficulty that one can follow the various steps and keep a clear idea of what has been proved and what remains to be established. Sometimes, on the other hand, a remarkably close approximation flows out of an extremely simple construction; and a case of this sort possesses a certain degree of inherent interest. Mr. James Smith of Brooklyn has recently put before us an approximate construction for duplicating the cube which stands at the head of this class, and which we reproduce herewith.

Let OC be the side of the given cube. Bisect OC at S, and complete the square OSKA. With radius KC and centers K and C, strike arcs meeting at P. Bisect OA at Q. Then the line PQ represents, to all intents and purposes, the side of the cube whose volume is double that of the cube on OC.

For the purpose of subjecting the construction to analysis, we take O as origin, OA as x-axis, and OC as y-axis. Let $OC = 2s$; then $OS = OA = s$. The point K has coordinates (s, s) and the point C has $(0, 2s)$. The distance $KC = s\sqrt{2}$. For the circles about K and C called for in the construction we have the equations

$$(x - s)^2 + (y - s)^2 = 2s^2,$$
$$x^2 + (y - 2s)^2 = 2s^2$$

On simplifying, solving simultaneously, and selecting that intersection which has x positive, we find for the coordinates of P the values $\frac{s}{2}(1 + \sqrt{3}), \frac{s}{2}(3 + \sqrt{3})$. Using the distance formula between P and Q, we get for the length PQ the value $\frac{s}{2}\sqrt{15 + 6\sqrt{3}} = t$. For the ratio of the volumes of the cubes on $2s$ and on t we have

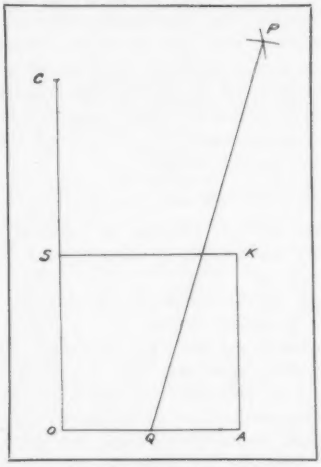
$$\frac{t^3}{(2s)^3} = \frac{\frac{s^3}{8}(15 + 6\sqrt{3})^{3/2}}{8s^3} = \frac{(15 + 6\sqrt{3})^{3/2}}{64}$$

In evaluating the numerator, if we take for $\sqrt{3}$ the value 1.732051, which is a trifle too large, we get for the expression $15 + 6\sqrt{3}$ the value 25.392306. For the square root of this the value 5.0391 is again a shade too great; for the cube of the last-named quantity the value 127.9555 is for a third time a wee bit over the mark. An upper limit for the ratio between the two cubes is then 1.9993.

If for $\sqrt{3}$ we take the value 1.73205 we get $15 + 6\sqrt{3} = 25.3923$. For the square root of this 5.039 is too small; for the cube of the last 127.94787 is again too small. From this a lower limit for the ratio between the cubes is found to be 1.99918. That a construction of such extreme geometric simplicity should give a non-Euclidean numerical quantity with an accuracy exceeding one-twentieth of one per cent seems quite remarkable.

NEW MICROPHONE FOR THE DEAF

AN article in *Licht und Lampe* (Sept. 9, 1920), describes an almost unnoticeable form of combined microphone and telephone by means of which defective hearing, short of total deafness, is largely remedied. The telephone transmitter is so very small that it can be inserted in the aural canal, and is then practically invisible. A fine twin flexible runs through the user's clothing and connects this with the microphone, which, with its battery, is mounted in a gentleman's attaché case or lady's hand-bag. The leather of the case or bag is pierced to allow the sound waves to pass freely, but these articles are practically indistinguishable from ordinary ones of their kind. A stud contact on the wrist permits the apparatus to be disconnected when not in use. Several elements can be provided for continuous service, to be switched on one after the other. In use, the bag or case is carried in the hand or laid on a table or counter.—Abstracted by *The Technical Review*.



A SIMPLE APPROXIMATE DUPLICATION OF THE CUBE

A SIMPLE PORTABLE REFLECTOMETER

FOR some time the U. S. Bureau of Standards has been engaged in the development of a simple portable reflectometer Recently numerous improvements have been made in this dvice which in its present form may be described as follows: The instrument is a sphere with a small segment cut away leaving a hole over which the surface to be tested is placed. The wall of the sphere is viewed through a small hole by means of a portable photometer, the spot viewed being screened from the test surface. A lighting tube set at an angle to the sphere surface is arranged to rotate about an axis normal to the surface of the sphere so that the direct light can be thrown on the test surface or on the sphere wall.

The theory of the integrating sphere shows that the reflection factor of the test surface is simply the ratio of the photometer readings in the two cases, no assumption being made as to the way in which the light is reflected from the test surface. Moreover, the reflection factor measured is not affected by selective reflection from the sphere walls. No accurate voltage adjustment of the lamps in the photometer and the reflectometer is necessary as both operate from the same battery. The use of a low-voltage flashlight lamp in the lighting tube makes the instrument very portable and convenient. By addition of an exterior light source, the same instrument can be used to measure transmission factors of clear or diffusing media.

Science and National Progress

Edited by a Committee of the National Research Council

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THE INTERNATIONAL AUXILIARY LANGUAGE PROBLEM

By Ward Nichols

Secretary of the Committee on International Auxiliary Language of the International Research Council

The National Research Council is a co-operative organization of the scientific men of America. It is established under the auspices of the National Academy of Sciences and its membership is largely composed of appointed representatives of the major scientific and technical societies of the country. Its purposes are the promotion of scientific research and of the application and dissemination of scientific knowledge for the benefit of the national strength and well-being.

THE steamship, the railroad, the telegraph and the cable have marvelously increased the facilities for commerce, travel and communication in all fields, and have revolutionized the conduct of business, as well as political and social affairs of the whole world to an extent little dreamed of by the people a hundred years ago. In the early part of the century it required a month to fifty days to make the ocean voyage by sailing-vessel from New York to London—a voyage attended with many dangers and a multitude of discomforts. Today the wonderfully developed steamship, with its double steel hull, divided into many water-tight compartments, with its powerful reciprocating or turbine engines and triple propellers, takes us the same journey in less than a week amid surroundings of comfort and elegance equaled only by the best of the palatial hostelries in our large cities. The port once attained, the railroad then takes us over a river here, under a river there, through the mountain beyond and across the great prairies, constantly striving to lessen distance, save time and to carry heavier loads and make more frequent trips; while the telegraph, carrying simultaneously three and four messages each way where formerly one message one way was the limit, is endeavoring to keep pace with the rapidly increasing business; and by the cable the merchant in New York or San Francisco, Buenos Aires or Valparaiso, translates the business impulse of the moment into almost immediate action on the same day at London, Havre, Hamburg, Shanghai or Yokohama! And who can say what the commercial development of the submarine and the airplane has in store!

Only a century ago Europe was practically the whole of the civilized world: Today the four corners of the earth are our immediate neighbors!

But in spite of the wonderful progress resulting from the development of the mechanical means of intercommunication—greater progress than was made during the previous five centuries—the means of oral and written intercommunication, aside perhaps from the developments in stenography, show no advance over conditions of five hundred years ago. The world has been obliged to carry on the great and constantly increasing volume of international intercourse in many different languages, all of them difficult of acquirement, and all this in the face of the existence of convincing evidence of the practicability and utility as well as the tremendous possibilities of an easily acquired neutral international language!

And the wonder of it all is, that our governments which spend millions upon Suez and Panama canals, that the very men who, as directors in our great national and international corporations, authorize by a nod of the head the expenditure of thousands of dollars to lessen a grade, or to tunnel a mile or two through a mountain to save going around it, who graveyard the Mauritania of today for the Leviathan of tomorrow, all in the name of efficiency, apparently remain blind to the frightful inefficiency and enormous cost of the conduct of modern business with ancient methods of communication.

The need for an international language for the purpose of intercourse between peoples of different speech and nationality was felt long before the present century. Even so far back as 1629, Descartes, though not the author of a project himself, formulated the two principal methods upon which all international language projects have been constructed: (1) the "a priori"[1] method, consisting of arbitrarily selected letters, syllables or words indicating an idea or group of ideas in accordance with a determined classification, and based in no way upon any natural language; (2) the "a posteriori" method, based on roots already existing in the natural language. It is interesting to note that although Descartes himself favored the *a priori* and rejected the *a posteriori* as "fit for vulgar minds," the projects which have thus far acquired an appreciable following have been founded on the *a posteriori*" method.

During the last two centuries there have been over one hundred attempts to solve the international language problem, but up to the advent of Volapük, in 1879, none of them had attracted more than passing notice, and the vast majority never progressed beyond the announcement stage. The history of the subject during the past thirty years may fairly be considered to have brought seriously before the public at large only three projects, and it is particularly interesting to note that while the mutual relations of these three systems have been avowedly competitive, they all have had in practice a common linguistic trend and thus all have served to develop and clarify the problem as a whole.

The project of an international auxiliary language may very properly be regarded as entirely analogous, at least in the first instance, to that of stenography, *i.e.*, as a special tool for special purposes which has no more bearing on the use and spread of existing national languages than stenography has had on that of printing and longhand. On the other hand, while it is relatively inconsequential how many different systems of stenography are in use, since each writer generally transcribes his own notes, the primary utility of an international auxiliary language is destroyed if essential agreement cannot be reached, and effort is consequently scattered among rival projects.

Real progress toward the solution of the international language problem may be said to have begun with the advent of Volapük in 1880. It was the invention of a Roman Catholic Bishop, Johann Martin Schleyer, of Litzelstetten, Baden, who is said to have possessed a knowledge of more than fifty natural languages. The vocabulary was supposed to be based mainly upon the English language, but most of the words were so mutilated as to entirely obscure their origin.

For the first three or four years the movement was largely confined to the German-speaking countries. In 1885 it was introduced into France and attracted a large and enthusiastic following, and the national propaganda society of that country numbered among its members many well-known men of science and letters. From France it spread rapidly into other European countries and into the Americas; and by 1889 there were

[1] A good illustration of the *a priori* method is the project "RO," by Rev. E. A. Foster, published by *The Ro Language Society*, Waverly, West Virginia.

nearly 300 Volapük societies distributed throughout Europe, America and the British Colonies, instruction books had been published in twenty-five languages, including Volapük itself, and the number of adherents was estimated at over a million.

There were three Volapük congresses, the last of which was held at Paris in August, 1889, just at the time when interest in the project appeared to be greater than ever and success seemed to be in sight. Early in the development of the movement dissension arose between Bishop Schleyer and the Academy (founded at the second congress in 1887) over the duties of the Academy and also as to the respective powers or authority of the inventor and the academicians, especially in the matter of the consideration and approval of proposed reforms in the grammar and vocabulary. At the third congress the quarrel was renewed and became so bitter that dissensions arose among the academicians themselves; and from this time on Volapük rapidly declined and within two years the movement was dead.

Although Volapük ended in failure as a project, nevertheless it is a valuable contribution to the linguistic side of the international language problem, and the history of this first significant attempt to solve the question is of great interest: in spite of its philological defects Volapük spread rapidly over the whole of the civilized world, and demonstrated the responsiveness of the world at large to the international language "idea."

In 1893, after nearly four years of inactivity, the Volapük Academy, materially reduced in numbers, again began to function, and under the lead of a new director, M. Woldemar Rosenberger (1893-1898), a St. Petersburg engineer, followed by Rev. M. A. F. Holmes, of Macedon, N. Y. (1898-1908), continued the work of amending and improving the Volapük grammar and vocabulary. The result was an entirely new project which was given the name of Idiom Neutral. In many respects it resembled Esperanto which had in the meantime appeared; in fact M. Rosenberger acknowledged that Esperanto was one of a number of projects which had a material influence upon the labors of the Academy. The language, however, was not used to any extent outside of the Academy itself, largely because of the activity and strength of the Esperanto propaganda. Indirectly, as experimental material, it probably did influence to a considerable extent the production of a later project, Ido.

From 1909 down to the present time Dr. G. Peano, professor of mathematics in the University of Turin, Italy, has held the post of president of the Academy, the organization now being officially known as "Academia pro Interlingua." The Academy gave up its special allegiance to Idiom Neutral and commenced the publication of an official organ called *Discussiones* issued at regular intervals as material becomes available, its columns being open to any international language project which its members may wish to discuss. Professor Peano together with some of his colleagues has worked out a system based essentially on Latin, with simplifications both in grammar and vocabulary, together with an adoption of recognized modern international terms, and a considerable portion of *Discussiones*, including official announcements of the Academy, appear in this form. *Discussiones* suspended publication at the outbreak of the war, but the Academy is again resuming activity as indicated by an 8-page bulletin which appeared in January of this year.

The author of Esperanto was a young Polish doctor, Ludwig Lazarus Zamenhof, born at Bielostock, Poland, December 15, 1859. His incentive was largely humanitarian and was inspired by his observation of the bitter feeling of animosity existing among the four racial elements making up the population of his native city, Russians, Poles, Germans and Jews. The constant state of strife arising from these conditions deeply impressed young Zamenhof, convincing him that diversity of language was one of the principal causes of international hatreds, and led him to the determination to do what he could to unite all men by means of a common auxiliary tongue.

When he was 14 years of age he entered the Second Classical Gymnasium at Warsaw from which institution he graduated in June, 1879, and entered the University of Moscow, graduating in 1885 with the degree of doctor of medicine. During his school and university life he devoted all of his spare time to an endeavor to create an artificial language. His first efforts were toward an *a priori* language with made-up words and arbitrary grammar, but as he progressed with his language studies—and he is said to have mastered Latin, Greek, German, French and English—he became convinced that an international tongue should be based upon roots common to several existing languages, with the simplest possible grammar; and along this line all his future work was carried out.

While still a student at the Gymnasium, he presented his first project tentatively to his companions, but efforts to propagate the language met with ridicule and criticism to such an extent that his parents interfered and he was obliged to promise his father that he would take no further steps publicly with his project until he completed his studies at the university. And so for five years up to the time he graduated from the University of Moscow, nothing more was heard publicly of his scheme, although during all this time he continued the work of perfecting and testing the language.

For two years after his graduation he searched in vain for a publisher who would be willing to print his work, and finally he published it himself under the title of "Lingvo Internacia," by "Dr. Esperanto" (one who hopes), on the 26th of July, 1887, at Warsaw, just at the time when Volapük was nearing the zenith of its success.

At first the new project called forth criticism and suggestions for improvements, to all of which Dr. Zamenhof gave careful consideration. He disclaimed all authority over the language, desiring to be considered merely as its "initiator," but he suggested that improvements should be introduced only after mature judgment and by some "central authoritative institution having indisputable authority for the whole Esperanto world, and not by any private person."

Early in 1889 the American Philosophical Society (Philadelphia) became interested in the international language problem in consequence of the Volapük propaganda, and proposed to arrange a congress to choose the final form of such a project. For a time it appeared as if Dr. Zamenhof's hopes for authoritative action of this kind were to be realized. He submitted his project, and the secretary of the Society published a translation under the title of "An Attempt Toward an International Language," by Dr. Esperanto, Warsaw, Russia." However, the proposed congress never materialized.

The demand for improvement grew with the development of the propaganda, and in 1894 Dr. Zemenhof published, through the official gazette, "La Esperantiste," a new grammar based upon the proposed changes, which was submitted to the then active Esperantists and rejected by a majority vote. This attitude was further emphasized by a "Declaration" adopted at the first international congress, since which time the Esperantists have consistently and resolutely refused to consider, either through their journals or in their congresses, efforts to introduce changes other than in accordance with the Esperanto "Fundamento," preferring to await and work for governmental recognition and authority.

One of the most interesting features of the Esperanto movement has been the international congresses, of which twelve have been held down to the present time. The number of delegates has varied from 600 at the first to from 1,200 to 1,700 at others; and to each congress many governments have sent official representatives. The first, and in many respects the most important congress, was held at Boulogne-sur-Mer, France, in August, 1905, and resulted in the formation of an organization for the control of all matters pertaining to the language and its propaganda. From this time progress was rapid and the propaganda spread into all quarters of the

world. The tenth congress was to have been held in Paris, August 2-10, 1914, but on the opening day when delegates from all parts of the world were congregating in the city or on their way there, war was declared and the congress was obliged to adjourn at the close of its first day's session. The following year, 1915, the eleventh congress was held in San Francisco, August 22-29, in connection with the Pan American Exposition. No further congresses were held until after the war, and the vitality of the Esperanto movement is evidenced from the fact that in August, 1920, at the twelfth congress, held at The Hague (August 8-14), 400 delegates were present representing 23 nations. At this congress measures were taken to reorganize the Esperanto movement, and Prague was selected as the meeting place for the next congress, the thirteenth, July 31-August 6, 1921.

It is impossible to give any reliable statistics regarding the number of adherents, but some idea of the growth of the movement may be gained from the fact that the number of Esperanto groups or societies as given in their official handbook had grown from 42 in 1902 to 1,575 in 1913. In 1905 there were 36 journals published, while in 1912 this had risen to 94 representing 31 countries, among them 26 devoted to special subjects, literature 9, national propaganda 59. During the war the number fell off very considerably, but since the armistice the list has grown rapidly and at last reports about 70 were being published.

Out of the meetings of a number of international congresses and learned societies held during the Paris Exposition in 1900, *i.e.*, five years before the first international congress of Esperanto, there was organized, the "Delegation for the Choice of an International Auxiliary Language." The official program and regulations for carrying out the plan were set forth in a "Declaration," which provided that the "choice of an auxiliary language belongs in the first instance to the International Association of Academies," and that in case of failure of the Association to act it should be the duty of the Delegation to appoint a Committee to undertake the task, and, further, that it should be the duty of this Committee "to create a Society for propaganda, to spread the use of the language which is chosen."

The meetings of the International Association of Academies were held triennially, but the matter was not officially laid before the Association until its third meeting, held at Vienna at the end of May, 1907. Up to this time the Delegation had received the adherence of about 300 societies and organizations of business men, tourists, etc., and the approval of over 1,200 university professors.

The Association decided that the question did not fall within its competence, "because history itself would eventually select the best universal language." The immediate result of this decision was the appointment of a "Committee of the Delegation," as provided in the Declaration. This Committee consisted of twelve members among whom were Professors Louis Couturat and Leopold Leau, authors of "L'Histoire de la Languages Internationales," and Professors Otto Jespersen and W. Ostwald.

The Committee met in Paris October 15-24, 1907, and after several sittings decided:

"That the Committee adopt in principle Esperanto on account of its relative superiority and the numerous and varied applications that have been made of it, subject to its being modified in accordance with the project IDO and the Secretaries' Report, and in trying to agree with the (Esperantist's) Language Committee." The Committee then declared "that the theoretical discussions are closed," and elected a permanent Commission "whose first task will be to study and fix the details of the language adopted."

Efforts were made to gain the approval and coöperation of the Esperanto Language Committee, but the matter became involved in controversy over the ultimate authority of the different bodies concerned and finally resulted in a complete rupture between the Esperantists and Idists.

Failing to obtain the recognition of the Esperantists the Permanent Commission turned its attention to the discussion and solution of questions left unsettled by the Committee of the Delegation and to the publishing of text-books and dictionaries of the language in accordance with the decisions and indications of the Delegation. The first text-books and dictionaries were published in the spring of 1908, and in March of that year was begun the publication of a monthly journal called "*Progreso*, the Official Organ of the Delegation for the Adoption of an International Auxiliary Language and its Committee; consecrated to the propagation, liberal discussion and constant improvement of the International Language."

In July, 1910, the Delegation (having achieved its object) was regularly dissolved, after having founded, in accordance with one of the articles of its program. The Union for the International Language, whose mission was to develop and to propagate the "International Language of the Delegation." The headquarters of the Union are at Zurich, and its affairs are directed by a "Direktanta Komitato" and an "Akademio."

From the time of the publishing of the first text-books and dictionaries the propaganda became very active, attracting in several countries numbers of former Esperantists, among whom were many counted as active propagandists. By the end of 1910 the movement had acquired considerable momentum and it appeared for a time as if it might equal or even surpass the Esperanto movement, but the constant introduction by the "Akademio" of changes and improvements from about this time up to 1913, making it impossible in many countries to obtain up-to-date instruction books and dictionaries, served to seriously check the propaganda. To avoid confusion so far as possible from the policy of progressive changes and improvements, "periods of stability" were adopted, with the intention that changes discussed and adopted by the Academy during each period should become official and binding only after the termination of such period. The first period closed on July 1, 1913, and the second period is to extend for at least ten years.

It is claimed (official journal *Progreso*) that at the outbreak of the war there were about 200 groups of national propaganda societies in all parts of the world, seventeen reviews or magazines published in various countries, and that adaptations had been made to fifteen languages. The first Ido congress was appointed to be held at Luxemburg, September 6, 7 and 8, 1914, but the war prevented the meeting. Efforts are now being made to organize a congress to be held at Vienna this year. Two text-books in English[2] have been published recently which include all changes and improvements made by the Academy up to the close of the first "period of stability," and an English-Ido dictionary is being prepared.

The aim of both the Idists and Esperantists is eventually to secure governmental recognition of an international auxiliary language, including its introduction into the public schools and its use in official international business. Their points of view and methods of attack may be summed up briefly by saying that the Esperantists believe that Esperanto in the form it has stood unchanged for thirty years, is good enough at least as a sort of working hypothesis until substantial governmental recognition for the international language problem in general can be secured, and that the most important work at present is to keep on steadily extending the everyday use of the language and educating the public to its utility and relative stability, carefully avoiding controversial details of ultimate possible improvements as apt to distract attention from the main issue of general use and shake confidence in the permanency of the movement as a whole.

The Idists, on the other hand, have laid special stress upon perfecting the linguistic details of the project as early in the development as possible and have consequently striven to

[2] "IDO," an "Exhaustive Text-book of the International Language of the Delegation, and Fundamentals of an Artificial International Language," by Dr. Max Talmey, New York; and "Complete Manual of the Auxiliary Language IDO," by the British Idistic Society, London.

keep up this process of change and improvement progressively along side of general propaganda similar to but more conservative than that of the Esperantists, even at the risk of shaking public confidence in the stability of the proposed language.

The war necessitated vitally important and extraordinarily intimate relations between many nations of different speech, and, together with the work of solving the many new and difficult problems incident to the period of readjustment, has aroused the world as never before to the consideration of all matters bearing upon international intercourse and has especially emphasized the irritation and inconvenience arising from the confusion of tongues. This has led to a renewal of interest in the solution of the international language problem and to the conviction that steps should be taken through non-partisan sources to bring about a thorough investigation and study of the whole subject, with a view to the eventual selection or approval of some one project. The continued spectacle of rival systems, each with its own body of adherents and each striving through narrow partisan methods to gain official governmental or other authoritative recognition, is very far from edifying and has at times undoubtedly tended to discourage the faith of the world at large in the outcome of the problem; for unless there can be essential agreement upon some one project, international language becomes merely a linguistic hobby and therefore of no use to civilization. On the other hand, the lasting benefit of a decision based upon the testimony of partisans of this or that project is doubtful. Decision should be made only after thorough and impartial investigation and study of the general problem and a comparison of the various projects.

The period of partisan controversy shows signs of coming to a close and to be replaced by a period in which the individual adherents will more and more lay aside old prejudices and turn the whole of their combined efforts into constructive channels, recognizing that each project has in the past contributed certain elements of discussion necessary to the final solution of the problem, independent of which side of the argument they have taken. An interesting and very ingenious attempt at combining selected elements from both Esperanto and Ido has lately been put forward by Dr. R. de Saussure,[3] under the title of "Esperantida." No matter to just what extent this or that particular side finally prevails, the discussion is highly important for securing public confidence that the fundamental questions have been thoroughly tried out and the possibility of overlooking important aspects thus eliminated so far as possible before any project receives final official approval.

It was in the belief that the time was ripe for taking steps to win the attention and consideration of responsible academic agencies to a thorough study of the problem in all its aspects, that the subject was brought to the attention of the International Research Council, at its meeting in Brussels, July 18-28, 1919. The following resolutions were unanimously adopted:

RESOLVED: (a) That the International Research Council appoint a Committee to investigate and report to it the present status and possible outlook of the general problem of an international auxiliary language.

(b) That the Committee be authorized to coöperate in its studies with other organizations engaged in the same work, *provided*, that nothing in these resolutions shall be interpreted as giving the Committee any authority to commit the Council to approval of any particular project."

Dr. Frederick G. Cottrell was appointed Chairman of the Committee, which is headquartered at the offices of the National Research Council, 1701 Massachusetts Avenue, Washington, D. C.

It is not the intention that this central Committee shall necessarily of itself enter upon an extensive investigation and study of the international language problem, but rather, in the first instance at least, to stimulate interest and centralize effort in the study of the question by and through responsible and competent academic organizations and educational institutions in this and other countries and then to act as a clearing-house for the exchange of information and plans between them; so the first work of the committee has been confined to efforts to awaken interest and to secure the organization of committees and working groups in certain learned societies and universities, and already a number of such committees and study groups have either been appointed or are authorized. The Committee will also help the individual university groups to build up their library equipment.

The first national response to the appointment of the International Committee was by the British Association for the Advancement of Science, at its Bournemouth meeting, in September, 1919, in the appointment from its "Section on Educational Science," of a committee "To Study the Practicability of an International Language." Mr. W. B. Hardy, Secretary of the Royal Society, was appointed Chairman, and as such becomes also the British representative on the International Committee; Dr. E. H. Tripp, Secretary of Section L (Education) of the British Association for the Advancement of Science, was appointed Secretary. This British Committee has been active during the past year, and at the annual meeting of the British Association at Cardiff, in August, 1920, an interim report was submitted covering its preliminary work and the Committee was continued for the coming year. The British Classical Association has also appointed a special committee to cooperate.

In this country the American Association for the Advancement of Science has authorized the appointment of a committee; the National Research Council has authorized the appointment of a delegate to a joint committee between the National Academy of Science, the American Association for the Advancement of Science and the National Research Council; and the American Council on Education (including The Modern Language Association of America), The American Philological Association and the American Council of Learned Societies. (The American representative of the International Union of Academies) and the American Classical League have already authorized or appointed committees on the subject.

The purpose of establishing these various committees at the very start is to insure that the approach to the subject shall be taken in an adequately broad and conservative manner and that no important aspect of the problem shall be overlooked.

The aim of the Committee on International Auxiliary Language is to gradually build up a large and competent group of investigators having both theoretical and practical knowledge of the problem, and so form a really adequate panel from which members for a central international commission, preferably under the League of Nations or whatever agency finally functions in that capacity, may ultimately be drawn to deal constructively and so far as possible authoritatively with the subject and insure competent pronouncement on details and the greatest possible stability of the final project for practical purposes of international communication. "Internationalization of thought is the motto of the twentieth century, the device on the banner of progress. Science, the Super-Nation of the world, must lead the way in this as in all other things. Amidst the clangor and the clamor of political and commercial strife, the quiet empire of knowledge grows, noiseless and unseen. Let all those who believe that this peaceful empire is destined to become the controlling force of the world assist in the attunement of its common language."[4]

[3] 8 Marianstrasse, Bern, Switzerland.

[4] F. G. Donan, in his preface to "International Language and Science."

SIZE OF THE POSITIVE ELECTRON

THE smallest particle of ponderable matter is the atom which has a diameter of a one hundred millionth part of a centimeter. Infinitesimal as this is it is a hundred million times larger than the positive electron whose diameter is 10^{-13} cent.

Notes on Science in America

Abstracts of Current Literature

Prepared by Edward G. Spaulding, Ph.D., L.L.D., Professor of Philosophy, Princeton University

THE RELATION OF MENDELISM AND THE MUTATION THEORY TO NATURAL SELECTION

THE main factors which Darwin presented as resulting, in their actions and reactions, in natural selection are three in number:

First. *Heredity*, by which the progeny tend to resemble their parents more than they do other individuals of the same species.

Second. *Individual variation*, by which the progeny tend to depart from the parental type and sometimes from the specific type.

Third. *Geometrical ratio of increase*, by which each species tends to reproduce more individuals than can survive.

Each of these factors is practically axiomatic, so little is it open to argument. No one doubts the *fact* of heredity, whether pangenesis, Weismannism or Mendelism be the correct expression of the mechanism involved. No one doubts the *fact* of variation; whether it is the "individual variation" of Darwin, the "fluctuating variety" or the "mutation" of De Vries. No one doubts the *fact* of geometrical ratio increase.

A moment's reflection will show that geometrical ratio of increase is a *quantitative* factor, giving an abundance of individuals from which to select; that individual variation is a *qualitative* factor, giving the differences which make a selection possible; and that heredity is a *conservative* factor, holding fast those characters which better fit the organism to its environment.

Now there is no possible outcome of the necessary action and interactions of these three factors that would not be a *selection* of some sort.

Three outstanding theories have been advanced since the publication of the "Origin," each involving an advance in our knowledge of the mechanism of heredity on the one hand and of the origin of variations on the other. Mendel's theory regarding the purity of the gametes, their segregation in the sex cells, and the whole complex Mendelian mechanism so admirably described by Morgan; all of these, fascinating and important as they are, deal with the *mechanism* rather than the *fact* of heredity. But it is the theory of mutation that has furnished most of the ammunition for the opponents of natural selection; and this in spite of the fact that De Vries, the originator of the mutation theory, expresses himself with great clarity as follows:

"My work claims to be in full accord with the principles laid down by Darwin and to give a thorough and sharp analysis to some of the ideas of variability, inheritance, selection and mutation which were necessarily vague in his time."

In 1904, when these words were published, there did seem to be a sharp distinction between the ideas of Darwin and those of De Vries. Darwin believed that individual, usually small, variations furnished the material on which selection acts; while De Vries thought that mutants, usually large variations, furnished the material. Both, however, believed thoroughly that natural selection was a *vera causa* of evolution.

But things have changed greatly since 1904. The work of Morgan, Castle, Jennings and a host of others has shown that many mutations are so small, from a phenotypic standpoint, that they are quantitatively no greater than the individual variations of Darwin; and that they are heritable in the Mendelian way.

Castle produced a perfectly graded series of hooded rats which exhibits almost ideally the steps by which a new form might be produced by natural selection. And Jennings says:

"Sufficiently thorough study shows that minute heritable variations—so minute as to represent practically continuous gradations—occur in many organisms: some reproducing from a single parent, others by biparental reproduction. . . . It is *not* established that heritable changes may be sudden large steps; while these may occur, minute heritable changes are more frequent. . . . Evolution according to the typical Darwinian scheme, through the occurrence of many small variations and their guidance by natural selection, appears more consistent with the data than does any other theory."

Many believers in mutation have been needlessly befuddled by the diverse meanings of "variations" as used by Darwin and De Vries. Darwin included in his "individual variations" both the "fluctuating varieties" and the "mutations" of De Vries. Phenotypically they cannot even now be distinguished. De Vries himself candidly admits that this was Darwin's attitude, thus proving himself more clear-sighted than many of his followers.

Just as Mendelism has to do with the *mechanism* and not the *fact* of heredity, so the mutation theory deals with the *nature* and not the *fact* of variations. Neither, in my opinion, has any implication that is antagonistic to the theory of natural selection.

In conclusion it seems that we are justified in maintaining that Mendelism and the mutation theory, while forming the basis of the most brilliant and important advances in biological knowledge of the last half century, have neither weakened nor supplanted the Darwinian conception of the "Origin of species by means of Natural Selection."—Abstract from an article in *Science*, February 11, 1921, by L. L. Nutting.

THE COMPRESSIBILITY OF DIAMOND

MANY of the properties of that remarkable form of carbon, the diamond, are known, but its compressibility has never been measured. The commercial value of a quantity of diamonds sufficient for such a determination is so great that the opportunity for making the determination would seldom present itself. It is not necessary for this purpose, however, that the material be in one piece or even in large fragments although, contrary to what is commonly believed, no apprehension need be felt in subjecting diamonds or any other homogeneous material to the enormous pressures required.

The method used has been described in a former publication from this Laboratory. Briefly, it is as follows: The material to be investigated is surrounded by kerosene and placed in a cylindrical, heavy-walled, steel bomb, one end of which is closed while in the other end is fitted a piston with a suitable packing. Pressure is applied by forcing the piston into the bomb by means of a powerful hydraulic press. In order to determine the compressibility it is necessary to measure the pressure and the decrease in volume. The pressure is measured by means of a small coil of "therlo" wire the resistance of which changes with pressure according to a known relation; and the volume-decrease is determined by the movement of the piston, which is measured with a dial micrometer. Pressures were read to 1 megabar (1 megabar = 0.987 atmosphere) and piston displacements to 0.001 mm. As a means of correcting for the compressibility of the kerosene, an exactly similar series of measurements is carried out with some other substance of known compressibility.

The diamonds were placed in a thin-walled steel capsule, and the comparison body was a Bessemer steel cylinder the volume of which was equal to the volume of the diamonds plus the volume of metal in the capsule. In order to remove any air

bubbles, the material having been placed in the capsule, was covered with kerosene and the whole evacuated.

With the apparatus used the most accurate measurements are obtained in the range from 4,000 to 10,000 megabars. Accordingly, it seemed best to make several series of readings within this range of pressure. Readings were taken at 4,000, 6,000, 8,000 and 10,000 megabars. Three separate runs were made with the diamond and two with the steel, but the first series with the diamond was subject to slight irregularities due to trouble with the electrical connections and was therefore neglected in the final calculations. The method for calculating the results and for making the various corrections is described in detail in the former paper already referred to.

The results show that the compressibility of diamond is remarkably low; indeed, of all substances whose elastic behavior is known, diamond is by far the most incompressible. Its nearest competitor, tungsten, is nearly twice as compressible (0.27×10^{-6}), and the majority of solids decrease their volume more than ten times as much for a given increment of pressure. If a diamond were buried 100 miles below the surface of the earth the pressure due to the superincumbent rock—a higher pressure than has ever been attained in the laboratory—would decrease the volume only about three-fourths of one per cent.

This is the lowest compressibility of any known substance.—Abstract of article by L. H. Adams of the Geophysical Laboratory, Carnegie Institution of Washington, in the Journal of the Washington Academy of Sciences for February 4, 1921.

PHOTO-ELECTRIC CURRENTS IN THE EYE

IN the January number of *Physiological Reviews*, a new publication edited for the American Physiological Society, Mr. Charles Sheard presents an important article on the subject of photo-electric currents in the eye.

The process by which the ether disturbance causes a visual impulse may be ascribed to (*a*) chemical action, (*b*) molecular strain and (*c*) electrical action.

According to the *chemical* theory it is presumed that certain visual substances (or possibly substance) in the retina are affected by light and that vision originates from metabolic changes produced in these visual substances. It is supposed that the metabolic changes consist of two phases; the upward, constructive or anabolic phase, and the downward, destructive or katabolic change. These anabolic and katabolic changes in various visual substances are supposed to produce the variations of sensation of light and color. This theory is complex. Numerous objections have been urged against its acceptance; for it is difficult, for instance, to see how this very rapid visual process can be due to a comparatively slow chemical action consisting of the destructive breaking-down of the substance followed by its renovation. Support was at first furnished the chemical theory, as it has ordinarily been presented, by the bleaching action of light on the visual purple present in the retina, but it has been discovered that the presence or absence of visual purple is not essential to vision and that its presence is of only secondary importance. For it is well known that the visual purple is lacking in the *fovea centralis* and it is also found to be completely absent from the retinas of many animals possessing keen sight.

The *mechanical* theory depends, in large measure, upon the theory of resonance in connection with chemical action. It is readily conceivable that a ray of light can cause a chemical decomposition of a substance in which the rhythmic excursions of an atom or atoms from, or round about, the center of attraction in a molecule are in exact tune with the waves of light falling on such atoms. The excursions may be so increased in extent by the rhythmic energy supplied by the light waves that the atoms will leave the parent molecules and produce new molecules. It is not as easy to see why the rhythmic excursions of atoms in the same molecule are also increased to the point of molecular rupture when the wave-motion of the impinging rays is not in tune or nearly so. But some photographic and mechanical examples help us out. For if a sensitive salt, such as silver chloride, is exposed to the action of the spectrum, we can plot a curve showing the sensitiveness of this particular salt to the different spectral rays. Such a plotted curve shows a rise in sensitiveness to a maximum followed by a decline; the maximum of such curve shows the place in the spectrum where the vibrations composing the beam of light are in tune with the vibrations of the chlorine atom in silver chloride, for example, the chlorine being that part of the molecule which is swung away and annexed to some other adjacent molecule.

The essential points in the mechanical theory of retinal stimulation as consisting of resonance effects coupled with chemical action fit in with many of the physical phenomena known as *photo-electric* actions. This term includes phenomena due to the action of light in liberating negative electrons from various metallic substances. It is known, for example, that there is a considerable influence of the wave-length of frequency of the light upon the number of electrons emitted and that curves plotted between frequency and rates of "leak" of negative electricity from metals such as sodium, potassium and rubidium show maximum or resonance effects. Likewise, salts which undergo decomposition in the light, such as silver chloride, are strongly photo-electric. We are, therefore, presumably dealing under the tenets presented to us in this theory with the expulsion of electrons due to resonance; the electrons are set in resonant vibration by the incident light and acquire sufficient velocity to enable them to escape from the atom. In the case of photo-electric effects from metals it has been possible to identify the valency electrons which play the part of chemical bonds with the photo-electric electrons which can be liberated by the action of light. From this point of view a photo-electric change and a photo-chemical change may be regarded as of the same character, consisting essentially in the displacement or separation of an electron through the absorption of energy from a light wave. We may thus have two kinds of photo-chemical action. In a primary or direct action the same valency electron which has absorbed the energy is itself released from its connection with a strange atom, while in a secondary or indirect action the electron which has absorbed the energy causes by collision the separation of an electron from an atom.

These various fundamental concepts are presented for the reason that there are various data afforded by the author's own experimental results which are in accord with certain of the principles underlying both the chemical and mechanical theories.

Mr. Sheard here describes in detail his general experimental procedure, makes a critical survey of the data obtained by other investigators, and concludes:

1. That positive retinal currents are manifested and positive electro-motive forces established when an eye is illuminated by light.

2. That the source of these electrical changes lies in the retinal structure or in the posterior part of the eyeball.

3. That luminous stimuli of different wave-lengths—from red to violet—give initially positive retinal currents. Hence all responses are of the same general type, and act in accordance with their luminosity.

4. That the stimulus-response relation is such that the curve representing it is concave to the axis representing the stimulus.

5. That fatigue is less pronounced in the case of the retina than in that of muscle.

6. That the time-relations of the responses or periods of latency after application of stimuli are of the order of 2/10 to ½ a second.

7. That there is a characteristic response to darkness as well as to light stimulation.

8. That the range of light vibrations under which animals' (frogs quite largely) eyeballs give definite photo-electric re-

sponses corresponds very closely to the range of vision of our own color sensations.

9. That photo-electric effects with sensitive cells may be obtained which are wholly analogous to phenomena obtained with eyeballs.

10. That experimental results point to the localization of two photo-electrical substances in the posterior half of the eyeball or that the retina is the seat of a double electrical movement which may consist of duplex changes in one substance or of two changes in two different components.

Research Work of the United States Bureau of Standards

Notes Specially Prepared for the SCIENTIFIC AMERICAN MONTHLY

FIRE TESTS OF BUILDING COLUMNS

A DETAILED report of fire tests and fire-and-water tests on over 100 building columns has recently come from press. This report contains results of an investigation which has been conducted jointly during the past six years by the Bureau of Standards, the National Board of Fire Underwriters, and the Associated Factory Mutual Fire Insurance Companies. An edition of 5,000 copies of this report has now been published by the two last-named coöperating agencies and copies are available at what is practically the cost of publication. The report contains 389 pages and numerous illustrations, curves, and tables. A small edition of the same report will appear in the course of the next few months as a Bureau technologic paper.

Copies of the complete edition, above referred to, may be obtained for $2.00 per copy for paper cover and $2.50 for cloth cover from the Underwriters Laboratories, 207 E. Ohio Street, Chicago, Ill., or from the Associated Factory Mutual Fire Insurance Companies, 31 Milk Street, Boston, Mass.

RADIUM

IT is probably not very generally known that practically all of the radium bought and sold in the United States passes through the hands of the Bureau of Standards. Any one in buying a radioactive material naturally wishes to know whether the substance contains genuine radium, and the determination of this is one of the important functions of the Bureau of Standards. It is practically impossible to sell articles depending on radium for their value without first obtaining the certificate of the Bureau. It has seemed worth while to issue a few facts concerning this subject for the benefit of those who may not be very well acquainted with radium testing as at present carried on.

Radium is a chemical element, one of the heaviest and most valuable known, being worth 200,000 times its weight in gold. It was discovered in 1898 by Madame Curie, a French scientist. It is found in nature as an ore, as a constituent of pitchblende in Europe, and of carnotite (found in Colorado and Utah) in this country.

Carnotite is an ore combining uranium and vanadium and either potassium or calcium. It is a low grade ore, in reality a sandstone cemented by the carnotite material. Five hundred tons of this ore produce one gram of radium, requiring 500 tons of chemicals and 1,000 tons of coal for its recovery. This amounts to between two and three parts of radium in a trillion of ore. The present market price is about $110 per milligram, or three million one hundred and twenty thousand dollars per ounce avoirdupois.

Radium is used to a small extent in radium-luminous paints, but chiefly in the treatment of cancer and other abnormal growths, for which purpose a sulphate, chloride or bromide of radium is used, and this is usually kept hermetically sealed in a metal needle or glass tube. The therapeutic virtue of radium lies in the power of its radiation to destroy tissue combined with the fact that normal tissue is more resistant to its destructive effects than abnormal tissue.

A radium specimen is measured by comparing it with a government standard of known size, the relative amounts of radium in the two being proportional to the rates at which they discharge an electroscope placed at a fixed distance, each acting alone. This method of measuring radium with its attendant necessary corrections requires a high degree of technical skill, and is not generally understood by the public. On account of this, as already mentioned, over 90 per cent of all radium recovered and sold in this country is sent to the National Bureau of Standards to be measured and certified, because after going through the tremendously expensive process of reducing the ores and recovering the radium it is practically impossible to market it without government measurement, and the government certificate.

Within the last six months, the radioactivity section of the Bureau of Standards has measured and certified over two million dollars' worth of radium for shipment, not only to nearly all parts of the United States. but to Canada, England, Holland, Denmark, France, Italy, Japan, India, Australia, Argentina, Brazil, Peru, and Porto Rico.

CIRCULAR ON THE PHYSICAL PROPERTIES OF MATERIALS

DURING the past few years, the Bureau of Standards has received numerous requests for information regarding the physical properties of materials, principally ferrous and nonferrous metals and alloys. Some time ago, the compilation of most of the available data on this subject was undertaken. The tables which were compiled as a result of this work were issued to a limited number of government establishments in mimeographed form.

As they seemed to fill a very real need, it was deemed advisable to issue them in the form of a Bureau publication, and Circular No. 101 has been the outcome of this work. The circular aims to present in readily accessible form the best available data on the strength and related properties of materials. Among those treated are iron, carbon steel, alloy steels, wire and wire rope, semi-steel, aluminum, copper, miscellaneous metals and other alloys, rope, rubber, leather, and wood. The tensile strength, proportional limit, percentage elongation in 2 inches, percentage reduction of area, Brinell and scleroscope hardness corresponding to a certain composition, density, and method of preparation are shown in most cases for the metals and alloys In addition, figures are given in many instances for the compressive and shearing strengths, moduli of rupture, and Erichsen values. The circular also includes definitions of the properties treated and references to sources.

TESTING OF PAPER

MANY requests are received by the Bureau for information in regard to the testing of papers and apparently interest in this subject is steadily increasing. For this reason it has been deemed advisable to issue a circular devoted entirely to paper testing. This is Circular No. 107 of the Bureau of Standards and takes up methods of testing paper and the

apparatus employed in the paper laboratories for routine work.

In the introduction, the size and importance of the paper industry is described and the various fibrous raw materials which go into paper manufacture are considered. During recent years a great deal of attention has been centered on the possibility of using grasses and crop plants for the making of paper. The Bureau has had considerable experience along this line and it is pointed out in the circular that the making of paper from such sources on a commercial scale is largely dependent on the cost of production and the availability of the raw materials. A rough classification is made of paper and a short definition stating that "paper is a matted or felted structure of fibrous material formed into a relatively thin sheet" is also given. The value of paper testing is brought out and it is emphasized that various testing methods must be used for papers for different uses. The physical qualities of paper are affected by changes in temperature and humidity and it has been found necessary to construct a special room in which constant conditions of 70° F. temperature and 65 per cent relative humidity may be maintained. This insures that all tests conducted will be on the same basis.

Under chemical testing are given the methods of determining the percentage of ash in paper and the amount of sizing. Two methods are given for the quantitative determination of rosin in paper, and qualitative tests for the various kinds of loading materials are outlined. Qualitative tests for various sizing materials are also given. The microscopical examination of paper and the estimation of the fibers from which it is made is now an important matter and the procedure of the Bureau is given in detail.

Finally, a working bibliography of useful books, periodicals, and government publications on this subject is included. Recommendations are made as to the size of sample which should be submitted for test and the fee schedule is given. It is important that proper methods be used in the sampling of paper and instructions are included as to how this should be done.

COLORED WALL PLASTER

GYPSUM wood fiber plaster is a commercial article made of calcined gypsum, wood fiber, and other ingredients. This wood fiber can be dyed with aniline dyes to produce any desired color, the dyes being fast to light. By the use of dyed wood fiber a colored gypsum plaster can be made. After this has been applied to the wall and allowed to set, the surface may be scrubbed with soap and water thereby exposing the colored fiber. Some very beautiful effects may be produced not only because of the great variety of colors available but also by using fibers of different sizes, by employing different proportions of fiber and by various surface treatments. Since both the colors and texture can be controlled, an artistic effect is insured for the finished wall. This wall is essentially a plaster wall and should be treated accordingly. It can, however, be scrubbed with soap and water whenever it becomes dirty or when the colors become dull. Technologic Paper No. 181 on this subject has been issued by the Bureau.

SAND-LIME BRICK

THIS is a building brick made of sand and lime and was first produced in the United States in 1901. By the action of steam under pressure, the lime is caused to combine with some of the sand forming a hydrated calcium silicate. This material acts as a bonding agent to hold the rest of the sand together. Most sand-lime bricks will compare favorably with "first common" clay bricks. They are characterized by their straight edges, parallel faces, and nearly white color. Their continued use in northern climates has established their durability under weather conditions but sand-lime brick is not a refractory material. The industry maintains a national association with which the Bureau coöperates in research work. Bureau of Standards Technologic Paper No. 85 contains detailed descriptions of the method of manufacture, while Circular No. 109 is devoted to description and specification of the brick itself. A good sand-lime brick for general purposes should have an absorption of not over 20 per cent, an average compressive strength of not less than 2,000 pounds per square inch and an average modulus of rupture of not less than 450 pounds per square inch.

CORROSION OF SOFT METALS

THE commercial soft metals include aluminum, tin, zinc, and lead. It has been shown previously—Bureau of Standards Scientific Paper No. 377—that a type of deterioration designated as "intercrystalline brittleness" may occur in lead under certain conditions whereby the metal crumbles to a coarse crystalline powder. The individual grains of this powder retain all the intrinsic properties of lead but the bond between the grains has been destroyed.

During the past year a series of corrosion tests has been carried on to demonstrate to what extent such deterioration may occur in other soft metals. The intercrystalline brittleness appears to be largely dependent upon the purity of the metal, and in the pure materials used in the test very slight evidence of such deterioration was obtained. A series of stress corrosion tests has been conducted to supplement Scientific Paper No. 377 and it has been shown that the simultaneous application of tensional stress to a specimen while corrosion is in progress is a powerful adjunct to deterioration by "intercrystalline brittleness." This is of practical importance, inasmuch as lead—because of its great weight—is often subjected to very considerable stress while in service. Thus the tendency to corrode and become embrittled is accentuated.

TABLES OF THE PROPERTIES OF AMMONIA

THE very accurate measurements which the Bureau has been making during the past few years on the thermodynamic properties of ammonia are only of use to engineers when tabulated in the form ordinarily employed for such data. The work completed is sufficient for the preparation of the table of the properties of ammonia liquid and vapor under saturation conditions, and such a table has been issued in mimeographed form. The values therein fortunately do not differ by more than a few per cent from those in tables now in general use. The measurements of the properties of superheated ammonia are now under way but it will be some time before the results will be available for completing the table.

MOLLIER DIAGRAM FOR THERMAL PROPERTIES

THE Mollier diagram is a chart used by engineers to represent graphically thermal properties of a substance thus serving as a convenient substitute for the usual tables of properties. As ordinarily drawn, heat content and entropy are used as the principal coördinates of the diagram. However, this diagram is not well suited for representing the properties of ammonia. An examination of the various modes in which the diagram might be drawn showed that the choice of heat content and a suitable function of the pressure produced a much more usable diagram for ammonia. A brief account of this work will be published in the Journal of the Society of Refrigerating Engineers.

CONSTRUCTION OF ELECTRIC RESISTANCE THERMOMETERS

THE experience of the Bureau in the construction of resistance thermometers may be useful to others. Therefore, a description of the resistance thermometers now in use and of the methods of construction employed has been prepared as one of the Bureau's scientific papers. A short note on the same subject is to appear in the Journal of the American Chemical Society.

Progress in the Field of Applied Chemistry

Notes Culled from Current Technical Literature

By H. E. Howe, Member of American Chemical Society

HELIUM

THE address of Dr. R. B. Moore before the Franklin Institute has now appeared as a reprint and may be unqualifiedly recommended to any interested in this story. The account of helium is one of the romances of science and its discovery represents one of the best examples of work in pure science which ultimately has great commercial application. The lecture in question gives the history of the discovery of radium, gives data as to its occurrence and discusses its properties at length. It then takes up in detail the initiation of the helium project, that is, the separation of this gas from certain natural gases in order that it might be produced in sufficient quantities for the use of dirigibles. The plants constructed for this purpose are described with the aid of illustrations.

The origin of helium in natural gas is of great scientific interest. The helium in the air is ordinarily believed to be due to radioactive changes going on in the uranium and thorium minerals in the earth's crust but the origin of this gas in natural gas confined in the earth is more difficult to explain. Two thousand pounds of uranium metal together with all of its disintegrated products will give 110 cu. mm. of helium per annum. It is estimated that the total amount of helium which has been evolved by the gas wells in the Petrolia fields to the present time is more than sixty million cubic feet. The area of the field being not more than 8 or 10 square miles it is inconceivable that sixty million cubic feet of helium could be produced by radioactive changes in the earth's crust within this area. Another explanation rests upon the supposition that the helium included below the earth's crust was brought from the sun at the time the earth was thrown off but this does not explain its localized occurrence. Again if helium has such an origin then it should contain other gaseous elements known to exist in the sun and Dr. Moore has already done some work to determine possible new elements to be found in the gas.

The commercial storage of helium presents one of the most interesting problems. It has been suggested that concrete chambers might be built in mine drifts and that these chambers should be lined with sheet copper to prevent loss of gas through the concrete. With such equipment the cost of storage per annum might be as low as one-tenth to one-fifth of a cent per cubic foot.

"It has also been suggested that helium might be stored in some of the salt deposits of New York. In this State some of the rock salt deposits are 60 feet thick and covered with a fairly heavy overburden. By drilling into the salt, and flushing out with a stream of water, a circular cavity could be made in the salt with a long neck, such cavity being 40 or 50 feet in diameter. The chamber would be something like a bottle with a very long neck, and helium might be stored in such a chamber under pressure satisfactorily. A series of "bottles" could be placed close together in the same deposit. It is necessary, of course, to know whether helium does or does not diffuse through salt in order to apply such a scheme practically, and this diffusion work is now being done by the Bureau of Mines."

CLAY FOR PAPER

A SHORT time ago there was considerable anxiety among paper manufacturers because they had not found in America the types of clay preferred as fillers upon which the finish and printing cost of book paper largely depend. The Forest Products Laboratory in Technical Note 139 gives the following information concerning a new American clay found suitable for this purpose:

"A highly colloidal clay which exists in large deposits in the intermountain regions of the United States has been found by the U. S. Forest Products Laboratory to be valuable as a loading material for giving finish and printing qualities to book paper. When this clay is used in conjunction with English china clay, the retention of the English clay is materially increased, and the paper produced has a superior finish and appearance, and a more velvety feel. The admixture of this clay similarly improves the retention of other fillers, and is especially desirable with some which have a low retention.

"The ability of the new clay to remain in suspension may make feasible the installation in paper mills of a central mixing plant, from which the loading material can be piped a considerable distance to the beaters, without danger of settling or clogging of the pipe lines, and with the assurance that the concentration will remain uniform. The properties and use of the new loading material are more fully described in a report which may be obtained from the laboratory on request."

STAINLESS STEEL

Canadian Machinery discusses methods for making stainless steel which consists usually of an alloy of iron and chromium from 0.1 to 1 per cent of carbon and from 12 to 14 per cent of chromium.

"The metal is cast in the usual manner into ingot molds, and the ingots are forged or rolled into bars or sheets. The material can be forged fairly readily into various forms if heated to a bright orange temperature; and if after forging the metal is allowed to cool in air, it will be found to possess good cutting qualities.

"Quenching in water enhances the hardness to a considerable degree, especially if the steel contains more than 0.4 per cent carbon, but oil quenching gives the best results. This steel resists formation of scale during forging to a great extent, and is therefore adapted to high-temperature uses, such as engine valves, distilling apparatus, and so on. The steel is slowly attacked by dilute or strong sulphuric and hydrochloric acids, practically unaffected by nitric acid, and is unaffected by nearly all the fruit acids and strong vinegar."

THE PROCESS OF AGEING CLAY

IT has been known from time immemorial that certain types of clay must be aged to make them satisfactory and there has been considerable discussion as to the factors of ageing and what changes take place in the clay itself. H. Spurrier in the February *Journal of the American Ceramic Society* discusses the result of his research and concludes that the growth of filaments algæ with the consequent evolution of both carbon monoxide and carbon dioxide is responsible for the change of plasticity of clays. This algæ theory will explain all of the various effects found. For example, the evolution of the carbon dioxide is found to continue for more than thirty-four days after pugging the clay, and like the change of plasticity to proceed more rapidly at temperatures between 80 and 90° F. than when below 60° F. When water was replaced by non-aqueous liquids development of plasticity was entirely inhibited while if treated with dilute solution of hydrogen peroxide the growth of the algæ was stimulated as was the evolution of carbon monoxide and carbon dioxide and there was a pronounced increase in viscosity.

At the same time plasticity was studied from the chemical side and based upon testing of three clays it was determined that the ratio of amounts of aluminum oxide and silica dis-

solved by caustic potash decreased rapidly with diminishing plasticity and, therefore, might well be used as a quantitative measure of plasticity. Ordinary determinations of silica and aluminum entirely failed to indicate differences in this character of a clay. The practical part distinguishes between sticky and plastic clay by filling them and the method of determining the ratio of alkali silica to alkali aluminum would appear to accomplish the same purpose and make it possible to express results in figures. The article quoted gives details as to methods of procedure and details as to results obtained in the tests.

LIME IN THE UNITED STATES

THE following figures which have been compiled by the National Lime Association indicate very forcefully the distribution of the uses of lime in the United States and convey a better appreciation of the importance of this common raw material:

	Per Cent	Tons	Price	Value
Building	28.5	913,714	$8.40	$7,675,197
Agriculture	12.2	391,134	8.40	3,285,525
Paper Mills	10.1	323,807	8.40	2,719,978
Refractories	9.7	318,896	12.80	4,097,819
Metallurgy	7.9	253,275	8.40	2,127,510
Alkali Works	4.53	145,031	5.30	768,590
Unspecified Chemical Uses	3.80	120,774	7.88	952,701
Dealers	3.50	112,210	8.40	942,564
Calcium Carbide	2.73	87,434	8.97	785,912
Water Purification & Softening	2.36	75,448	7.90	596,667
Tanneries	2.30	73,738	8.40	619,399
Acids	1.20	32,388	7.80	298,660
Bleaching Works	1.18	37,905	8.12	306,726
Sugar Factories	1.10	35,266	8.40	296,234
Glass Works	1.10	35,266	8.40	296,234
Soap	.93	29,599	6.83	202,028
Silica Brick	.83	26,517	6.90	182,659
Phenol	.78	25,002	7.86	196,463
Coke Oven By-products	.765	24,451	7.15	174,437
Explosives	.74	23,735	7.30	173,129
Wood Distillation	.43	13,986	8.70	121,678
Ammonia Works	.43	13,975	7.14	99,831
Cyaniding	.39	12,512	9.55	118,274
Gun, Cotton & Gelatine	.34	10,755	8.30	88,784
Sewage Purification & Neutralization of acid water	.30	9,514	7.23	68,668
Glue Manufacture	.28	8,822	8.94	78,599
*Undistributed	.24	7,790	7.29	56,621
Sand-lime Brick	.23	7,417	8.00	59,357
Disinfectants	.19	6,059	8.48	51,438
**Undistributed	.14	4,481	7.35	32,966
Lubricating Grease & Renovova of butter, etc.	.106	3,395	8.35	28,410
Gas Plant By-products	.074	2,371	8.15	19,309
Cotton Thread & Woolen Mills	.07	2,117	10.13	21,425
Nitrates & Glycerine	.064	2,059	6.23	12,486
Spraying	.06	1,813	9.23	16,706
Salt Refining	.056	1,791	7.48	13,388
Dehydration & Mfg. of Alcohol	.048	1,535	6.94	10,638
Kalsomine	.03	999	9.07	9,076
Polishing & Buffing Compounds	.01	384	11.50	4,424
Polish Salts	.005	176	8.01	1,409
Coal & Water Gas Purification	.0054	171	11.45	1,959
Flour Mills	.005	164	10.88	1,785
Pottery & Porcelain Mfg.	.005	129	9.40	1,213

*Calcium acetate, aluminum hydrate, borum products and precipitated calcium carbonate.

**Candles, corn products, dyes, rubber, medicines, varnish, graphite, gold and platinum refining, slag cement, print works, tobacco, copper, and file works, sheep dip, etc.

DIAMOND POWDER

DIAMOND powder in oil is generally used as an abrasive for cutting facets on diamonds and sharpening points where very hard abrasive is required and trial has shown nothing else to be so satisfactory. After a time the powder becomes dirty, the cutting points become covered and its efficiency is lowered. Some maintain that a part of this powder becomes converted into graphite during the polishing operation but Richard C. Berger writing in the February 2 number of *Chemical and Metallurgical Engineering* holds that no temperatures or pressures are reached in the polishing operation which would cause the conversion of crystalline diamond powder into graphite. The recovery of the diamond dust is, however, important and the following method of refining the waste is given:

METHOD OF REFINING WASTE

"Extract the oil present in the waste by shaking thoroughly the waste paste with acetic ether or benzene, and allow to settle, decanting the clear supernatant solution after the paste has settled, which will take anywhere from ten minutes to three hours. Repeat several times until the deposit is free of oil, which state can be seen when the solid particles settle readily. The oil must be completely removed, as even small amounts will cause considerable annoyance because of the disagreeable odors, generated during the acid treatments and difficulties in filtering the residue. If desired, the solvent used for the extraction of the oil can be recovered by distillation.

"Dry the paste which has been freed from oil on a steam table or in a hot air bath at a temperature not exceeding 130 deg. C. until it is free from solvent, and treat in an evaporating dish under a chemical hood with strong nitric acid. Heat over a free flame, adding nitric acid until there is no further action, but do not allow to go to dryness. Dilute with water, allow residue to settle, and decant the supernatant liquid. Repeat the washings and decantations until the deposit is clean. Dry the residue on a steam table or in a hot air bath at a temperature below 130 deg. C.

"Heat the dried powder in an evaporating dish with strong hydrochloric acid under a hood until no further action, but do not carry down to dryness. Dilute with water, allow residue to settle and decant the supernatant liquid. Repeat the dilution and decantation until the solid deposit is clean. Put in an evaporating dish and place on a steam table or in a hot air bath below 130 deg. C. until dry.

"Melt solid sodium hydroxide in a wrought iron crucible. Remove the flame and allow to cool from red heat to dark and while the mass is still molten add the dried residue, stirring with a platinum wire or iron rod. Place a cover on the crucible and heat gradually to dull red heat. Cool until the sodium hydroxide is solid and then leach out the crucible by placing it in water and heating until all the sodium hydroxide is dissolved. Wash the solid particles in an evaporating dish or in a beaker by repeated decantation with water until clean. Dry the deposit, which should be clean, bright and crystalline diamond powder.

"If there should be considerable black particles of amorphous carbon (graphite) present, these can be removed by adding the dried powder to a solution of specific gravity approximately 3.2, allowing the crystalline diamond particles to settle and pouring off the suspension of carbon particles."

LUBRICATION

A COMMITTEE on Lubricants and Lubrication was appointed by the British Department of Scientific and Industrial Research in 1917 and has made several progress reports. It has now published a final report in which in addition to several specialized papers there appear recommendations for future research on lubricants and lubrication. It is always helpful to those engaged in research to have stated clearly the work

which is most needed and the following summary therefore is quoted from the report in question:

"(1) To isolate and determine the nature of the hydrocarbons in mineral lubricating oils which especially promote the properties of viscosity and 'oiliness.'

"(2) To determine the classes of hydrocarbons desirable in lubricants required to work under high pressures and high temperatures, particularly as regards their relative stability under the conditions obtaining in internal combustion engines, steam engines and air-compressors.

"(3) To study the causes and means of preventing the formation of carbonaceous deposits from lubricating oils under the conditions named in (2), with special reference to the nature of the hydrocarbons, sulphur compounds and resinous constituents of such oils.

"(4) To study the causes of emulsification in circulating oiling and in splash systems, with special reference to (a) the influence of the sulphur compounds in mineral oils, and (b) the characteristics of oils with non-emulsifying properties.

"(5) To study the causes of oxidation in circulation oiling systems, also the causes of formation of oxidation products in bearings and on bright metal surfaces.

"(6) To determine the direction in which the processes of manufacture can be modified so as to lead to the production of lubricating oils of improved types.

"(7) To discover new methods of analysis which will enable the chemist when examining a lubricating oil in the laboratory, besides determining its viscosity, specific gravity, flash-point, etc., to determine the constituents of the oil and with the help of the knowledge gained under (1) to (5) to measure its ability to reduce friction and to meet the conditions of speed, load, temperature and atmosphere in which it is required to work. Much of this information can only be ascertained today by the costly method of trial.

"(8) To elaborate further methods of producing lubricants synthetically in order to meet special requirements. Dicresylcarbonate, for example, has been used as a lubricant. Reduced naphthenes, glycerides of naphthenic acids and cinnamenes have been prepared and shown to have lubricating value. It might be found possible to produce lubricants whose rate of change of viscosity is less and whose freezing point is lower, than is the case with existing lubricants.

"(9) To prepare in a pure state the esters met with in animal and vegetable lubricating oils and determine their relative lubricating values.

"(10) To investigate the claim made by Messrs. Wells & Southcombe, lately propounded in a paper read before the Society of Chemical Industry, that the free fatty acids present in commercial fixed oils are the active constituents which enable these oils to improve the lubricating value of mineral oils, and to investigate further whether the addition of such acids to mineral oils may in certain circumstances improve their lubricating value.

"(11) To investigate the colloidal nature of lubricating oils and its bearing upon lubricating problems.

"(12) To study the effect of ultra-violet light, sunlight and ozone upon lubricating oils.

"(13) To investigate the phenomena of dissimilar surfaces (oil and metal) in contact, especially in relation to the property of 'oiliness.'"

CLOTHS FOR MECHANICAL USES

JAMES W. COX, in the March number of *Mechanical Engineering*, discusses this question in an interesting manner and gives details concerning special uses of cloths for mechanical purposes. The tabulation of uses gives more than fifty items without pretending to be complete and the large industries in which cloth is used mechanically number more than thirty. Special mention is made of asbestos cloth which is an unusual product unlike any other cloth because of its heat and flame resisting qualities and, second, its neutrality to the action of acids and alkalis.

"For these two reasons it can be used in places where no other fabric can. The cloth is usually of heavy yarns and a plain weave, varying in closeness of mesh and thickness as the purpose requires.

"The great bulk of this cloth goes into steam packing. It is invaluable in this respect. In this are included gaskets and cut washers. The next largest amount goes into brake linings of all kinds, principally automobile. These may be entirely asbestos or wire warp with asbestos filling. Clutch facings come next in volume.

"Filter cloths of various degrees of openness and thickness are used, mostly in chemical plants. Wire backings may be used in this work. This type of filter cloth is also used in making such gases as oxygen and hydrogen, and in such plants where refuse or sewerage has to be disposed of. The cloth is easily cleaned by subjecting to fire.

"In the electrical industry asbestos cloth is used mostly in webbing or tape form in the manufacture of armatures, etc., and greatly in wire and cable manufacture. Tubing of this material is used also in cable manufacture and gives excellent protection.

"For fire doors, heat screens, and curtains a heavy fabric is used, either plain or with a wire warp. Theater curtains are of this type. Iron and steel mills use this cloth around furnaces, etc. Light asbestos cloth is used to wrap asbestos or magnesia packing, but in general heavy cotton sheeting or light duck is best for this purpose."

RESULTS OF TESTS WITH URANIUM STEELS

Iron Age prints the following abstract of results reported by E. Polushkin on uranium steels.

"The charge was composed of turnings and scrap and was melted down with lime. The first slag was removed and the steel refined under a second basic slag. The time of the heat was 4 hours 5 minutes. Additions in the furnace were ferromanganese and ferrosilicon and in the ladle carborundum and ferrouranium. The latter alloy was sometimes added in the furnace, sometimes in the ladle. When in the ladle from 70 to 75 per cent recovery of uranium was sometimes obtained, but generally the percentage obtained in the steel was irregular, often less than 50 per cent.

"Physical and other tests show no difference in results whether the alloy was added in the furnace or the ladle. As a rule two ingots were obtained, weighing about 120 pounds each.

"The results showed the steel to be full of defects such as blowholes and pipes. It is certain that these defects have their origin more in the method of steelmaking than that they are caused by the uranium.

"In steels with medium carbon, that is, 0.25 to 0.45 per cent, the uranium was found to raise the elastic limit and ultimate stress without affecting the ductility, or even raising it, also, Brinell tests show that uranium increases the hardness of steel. One heat with uranium and nickel gave very good results, showing ductility superior to ordinary nickel steel or chrome vanadium steel. The tests in certain other heats, however, did not show any favorable effects of the uranium."

READING LIST OF VITREOUS ENAMEL ON STEEL

IN a list of various aids to research, bibliographies must be written near the top and whenever such lists of references appear those interested in the particular field or related subjcts are glad to be informed of it. The reading list, the title of which is given above, has been prepared by Clarence J. West and begins with the literature of the year 1907, inasmuch as the literature of the ceramic industry is very well covered up to the year 1906 by the Bibliography of the Clays and the Ceramic Arts compiled by John C. Branner. The abstracts reproduced in the bibliography have been abbreviated or omitted where the title indicates the scope of the article. A reference to the original abstracts noted in the bibliography will enable the investigator to eliminate those which may be considered unsuitable to his own purpose.

Progress in the Field of Electricity

Summaries and Excerpts from Current Periodicals

By A. Slobod

ELECTRO-CULTURE

In his inaugural address delivered before the Institution of Electrical Engineers, London, President Llewelyn B. Atkinson gives a critical review of the recent progress in electro-culture. The position of the problem of electricity in agriculture does not, in his opinion, reflect great credit on our science.

Sir Oliver Lodge, in the fifth Kelvin lecture, in 1914, gave the results of experiments he and others had carried out, and, for some years past, reports have been periodically circulated of the great increases in crops of various sorts which have been obtained by the use of electrical discharges from wires suspended a few feet from the ground. But the results have been confused and contradictory and certainly have not reached a position of any degree of scientific certainty. This can be explained by the difficulties and uncertainties of crop experiment on a field scale with the variation in quality of soil, working methods, time of planting, etc. In the opinion of the author careful pot and plant laboratory experiment offers the greatest opportunity of determining the causes of the effects that have been observed.

During the war a representative committee under the chairmanship of Sir John Snell was formed and has since issued an interim report, dated April 2, 1919, describing certain preliminary field, small plot and pot experiments carried out. The results of these experiments were by no means conclusive, as is stated in the report; nevertheless, one or two definite results emerged: (1) That, with currents of the order 10×10^{-9} ampere per plant passed from a charged wire through the air to the plant, the results of an electric current are clearly injurious. (2) That, in the case of young plants at least, the vegetative growth of plants was accelerated by currents of the order 0.3×10^{-9} ampere.

After reviewing for the benefit of the electrical engineers the scientific principles of horticulture involved in the solution of this problem the author states that while there is nearly always an air of mystery about the discussions of electro-culture the questions to be answered are simple. Does any system of electrification promise to increase the quantities of the availability of any of the primary food necessities of the plant or to augment the rate of or total absorption of the plant foods, and if so, at what cost? It may be at once said that the presence of a highly charged conductor with a corona discharge therefrom cannot augment the quantities of any of the food materials necessary in the soil except the nitrogen. It is conceivable, but improbable, that it will increase the rate of solution of the natural soil elements. The possibilities are: (1) Direct stimulation of growth processes, in fact replacing sunlight. (2) Increase of transpiration of water. (3) Decrease of evaporation from the soil, equivalent to providing more moisture. (4) Production of nitrates. (5) Ionization of nitrogen or carbonic acid so as to be more readily absorbed by the soil bacteria or the plant. (6) Sterilization of the plant.

Of these (1), (2), (3) are purely electrical if they exist; they are direct actions and would occur in the region immediately under the wires. Many experiments have shown, however, that the effect, whatever it is does not occur necessarily directly in the near neighborhood of the wires used to maintain the electric stress, or to give the electric discharge, but that the effect may be to one side or the other of the electrified plot, and it appears that this result is not strictly electrical at all, but due to something produced in the neighborhood of the wire, which is heavier than air, but can be diverted by the prevailing wind.

If this is the case we are thrown back on the causes (4), (5), (6). The researches of Earl Warner and Jakob Kunz at the University of Illinois have shown that the corona discharge in air causes ionization of nitrogen, oxygen and carbonic acid; the researches of Prof. J. Strutt and Dr. Lowry upon the action of the silent discharge have shown that active forms of nitrogen are the result. The discharge in carbonic acid produces oxygen; in air with water, ammonium nitrate. The fact then that chemical active ions and compounds are produced which would move with the wind, points to these being the cause of the observed results. If the results were due to the production of nitric acid one would expect the increase to be greater the greater the current, but, on the contrary, the results were better with smaller currents. A similar agreement would seem to hold in the case of the ionization of carbonic acid.

The results obtainable in increased crops by the sterilization of the soil are very remarkable. Recent researches have shown that one of the most powerful sterilizing agents known is oxide of nitrogen, one part in 50,000 parts is sufficient to kill any germ with which it comes in contact. It seems to me, therefore, that we have here the possible solution of the effect of electrical discharges over plants. A crucial experiment would be to compare the action on plants growing in soil, and in water with the plant foods dissolved therein. If the water-culture plants were unaffected and the soil-grown plants benefited, then I think the case for soil sterilization would be made out; if the reverse it would point to nitrate being the cause. It would appear as if the different effect of strong discharges and weak discharges may be in this, that strong discharges produce products other than oxides of nitrogen while weak discharges produce the sterilizing effect described.

The Wohler process of so-called electrification of seeds has also been boomed by the papers. The process consists in placing the seeds in a solution of 2½ to 5 per cent household salt and passing an electric current through the solution, then drying the seeds and sowing them. Even assuming the solution to be effective, it is difficult to see what result would accrue from the electric current unless it was a possible deeper or more rapid penetration by electro-osmosis. Careful experiments however by Dr. Hall at Rothampstead led him to conclude as follows: "The writer is not prepared on present evidence to say that the process never succeeds, but the risk of failure seems so great that the farmer should look upon it as an adventure which may or may not prove profitable." Mr. Martin Sutton, of Reading, after exhaustive trials, arrived at what was practically a negative result.—*Journal of the Institution of Electrical Engineers*, December, 1920, pp. 13-15.

OIL PROSPECTING BY ELECTRIC WAVES

Mr. R. S. Bruner, an electrician of twenty years' experience, has been demonstrating in Oklahoma City, Okla., what he calls a radio oil-locating instrument. He has already made field tests with his truckload of equipment. Without knowledge of the territory in which he was operating, and without having been advised of formation in test wells, his estimates of the depth of oil sands have been within 30 feet of their actual depth. Where no sands had been discovered he reported that no sands existed to the depth of the instrument's range. Something like 40 setups have been made, and no errors have been recorded in Bruner's conclusions.

The equipment consists of two engines and generator sets connected in parallel to supply the source of power and detector units and receiving equipment. The generator sets supply direct current at 40 volts. This applied to a 1-kilowatt motor-generator set creates 110 volts of alternating current,

higher voltage is then obtained through a step-up transformer. Connections are made from the high-voltage transformer through a suitable oscillation transformer, condenser and choke coils to earth contacts. This comprises the disturbing element and the equipment is all mounted on a truck which is readily transported.

A surveyor's transit is used in making a location for a test. Five earth connections with the disturbing machinery are then made, two of them set 100 feet apart in the magnetic north and south, and the other two at right angles and 50 feet apart. The master earth connection is a fifth rod which is placed in the exact center of the outline of the four other earth terminals. The detector units and receiving equipment consist of three complete radio receiving instruments, two of which are evenly balanced. The third acts as a detector in approximately the same manner as a galvanometer acts in a Wheatstone bridge arrangement. Through the aid of a number of vacuum tubes and honeycomb inductance coils properly connected and adjusted to the earth connections, an instrument of extreme sensitiveness is produced which reproduces the slightest variations through telephone receivers.

Working in unison with the receiving equipment are two instruments that verify by illustration that which the receiving instrument gives to the ear. One is a sensitive ballistic galvanometer and the other a photographic apparatus. Mr. Bruner is convinced that the resistance theory heretofore employed in tests with instruments of this nature is wrong. Directing his attention to radio apparatus and applying it to different substances below the earth's surface he was convinced that the different sounds obtained from distortion of wave lengths directed and adjusted to different materials in the earth's crust would, when calibrated to known standards, denote the presence or absence of materials.

The tests Mr. Bruner made are carefully charted both as to sound from the receivers and readings of the ballistic galvanometer, the photographic device furnishing a permanent record. Results in tested areas have come within a few feet of accuracy, and an accuracy within 50 feet is guaranteed by Mr. Bruner.—W. F. Kerr, *Electrical Review*, Chicago, Vol. 78, pp. 145-146, Jan. 22, 1921.

WORLD'S FIRST 220,000-VOLT POWER TRANSFORMER

THE line voltage of 220,000, which has been tacitly agreed upon as being the approximate economic potential for the interconnections of the Western power systems, constitutes a very abrupt step in the curve of maximum transformer voltage. Nevertheless, there is every indication that the use of 220 volts will be attended with just as much success as that which characterized the first operation of 150,000-volt apparatus. A definite move in the direction of the 220 kilowatt pressure was made by the Southern California Edison Company last summer when an order was placed with the General Electric Company for four water-cooled, 50-cycle, 8,333-kva. transformers arranged for operation at 220,000 volts, stepping from a generated voltage of 11,000. These transformers are now being manufactured in the Pittsfield works of the General Electric Co., and their features are discussed by Clinton Jones in *Electrical World* for February 5, 1921, pp. 301-303.

The extensive investigations and experience of the General Electric Co. have proved the great advantages of the circular coil for high voltage transformers. After discussing these advantages in detail the author proceeds to describe the transformers under construction. It is of the "core" type with two groups of windings on separate core legs for each phase. The line end of high-voltage winding is brought out through a new standard oil-filled 250,000-volt bushing which is interchangeable as between the transformers and high tension oil circuit breakers. It will be interchangeable with any other bushings for 220,000-volt apparatus which may be furnished later. The external shell of this bushing consists of two porcelain pieces above the transformer cover, one porcelain piece below the cover and an intermediate metal cylinder which is flanged at the upper end to support the bushings. This metal portion always extends below the transformer oil level to avoid any possibility of corona in transformers having an air space between the oil level and cover. A metal tube extends from top to bottom through the center of the bushing, and the intervening space between this tube and the porcelain shell is filled with transil oil and concentric cylindrical insulating barriers. The glass chamber at the top provides space for expansion of the oil and indicates its level. The joints between the shell sections are made with treated cork gaskets compressed locally by numerous bolts engaging metal clamping rings. The central tube serves as the conductor when used in a breaker and as a conduit for a cable conductor in a transformer. The bushing has a dry flash-over voltage of 660,000. The lighting flash-over is estimated at more than twice the normal frequency figure and is equal for wet or dry conditions. In the event of any high impressed voltages the bushing will not puncture but will arch from the terminal to the ground.

The containing tank is of the "oil conservator" type, having a separate chamber for oil expansion. The principles involved in this construction are the elimination of the usual air space above the oil in the main tank and the isolation of the hot oil and transformer insulation from the surrounding air. The main tank is always completely filled with oil, and pressure is prevented by opening the auxiliary tank to the outside air through a breathing device. Any accumulation of moisture in the auxiliary tank due to condensation is caught in a sump and may be drawn off through a pet cock at the bottom. This construction eliminates "breathing" in the main tank and keeps the oil absolutely dry. It avoids explosions due to a possible mixture of air and gas formed from hot or decomposed oil. It protects the oil from "sludging," and preserves the transformer insulations.

ELECTRICAL AIDS TO NAVIGATION

EXPERIMENTS were carried out at Brest with the object of making it not only possible, but easy, for a ship to enter or leave port with safety in thick fog. An armored cable is laid on the sea bottom along the channel leading in to the port, and the sea end of this cable is earthed. The cable is fed with alternating current having an audible frequency. In the experiments dealt with a current of 2.5 amp. was employed. The cable current creates in the space around the cable an alternating magnetic field of the same periodicity as that of the current. The lines of force are somewhat complex, and the distribution was investigated both in the sea and above the surface. In both cases the lines are in planes perpendicular to the cable. The apparatus on board the ship comprises two vertical coils 2.5 cm. $\times$ 10 m. for receiving the current induced by the cable field. Each coil has two windings of 60 and 10 turns, respectively; the first coil is athwart ships and the second, lying fore and aft. Leads are taken from these coils to the listening point on the bridge, and by using an amplifier the signals transmitted along the cable have been heard at distance of 2,000 m. When the ship approaches the cable at right angles, the receivers of the first coil give gradually increasing signals, while stronger signals are obtained on the second coil when running parallel to the cable. Two horizontal coils (2.5 m. x 1 m.), one to starboard and the other to port, as far apart and as high as possible, will receive signals at ranges up to 600 m. from the cable. The one which is nearer the cable will give the stronger signals, and by using two such coils it is easy to determine on which side of the ship the cable lies, when the ship is running parallel to the cable. Dirigible balloons and aircraft generally can follow a submerged "leader" cable if they are properly equipped. The range of reception of signals at 200 m. altitude is about 3,200 m. in breadth. At 600 m. it is stated that the range is 5 km. on either side of the cable. The cable used at Brest was 80 km. long, extending past the dangers of Ouessant and the Pierre Noires, the sea end of the cable being at a depth of about 100 m.—W. A. Loth, *Comptes Rendus . . .* de l'Academie des Sciences, Vol. 171, pp. 668-669. October 11, 1920.

Survey of Progress in Mechanical Engineering

Prepared Under the Auspices of the American Society of Mechanical Engineers

MARTIN ROTOR BALANCING MACHINE

DESCRIPTION of a simple device for balancing rotary bodies of particular interest because of its great sensitiveness. This latter is such that, for example, when balancing a rotor of 10,000 kg., a variation of 1 kg. cm. can be easily discovered by sliding a weight of 1 kg. along the beam. This corresponds to a deviation of the center of gravity of the rotor in a horizontal direction off the axis of 0.005 mm. or approximately one-fifty-thousandth of an inch.

The same result is expressed in a different way, as follows: When balancing a 10-ton Zoelly rotor of 6 ft. diameter, an overweight of 10 grams (one-third ounce) on its circumference, or one-millionth part of the rotor's weight, can be readily detected.

Furthermore, the apparatus indicates the correct plane in which this overweight lies and in which its moment acts. These results are obtained without rotation, as it is merely necessary to turn the body to six or eight fixed positions and when actually balancing no rotation takes place. Because of this the method is not affected by the inertia of the body and the angle of lag cannot affect the results.

The machine (Fig. 1) consists of two main portions arranged to support the shaft of the rotor to be balanced. At one end the shaft is hung in a universally jointed stirrup and at the other in a bearing which is mounted on a short arm of a steelyard lever.

Having placed the rotor to be balanced in the bearings, the main weight of the steelyard is adjusted so as to bring the arm into equilibrium. The rotor is then turned a few degrees and the arm again adjusted by moving the jockey weight; this adjustment is recorded. The rotor is then turned through another section, and the necessary adjustment again made by means of the jockey weight, and so the process is continued for a complete revolution. The results are plotted to a horizontal base, and the sine curve obtained shows a maximum and minimum which indicate the points at which the center of gravity is farthest from, and nearest to, the supporting point of the balance. By multiplying the jockey weight by its displacement, a moment is derived from which the eccentricity of the center of gravity and the necessary correction are obtained.

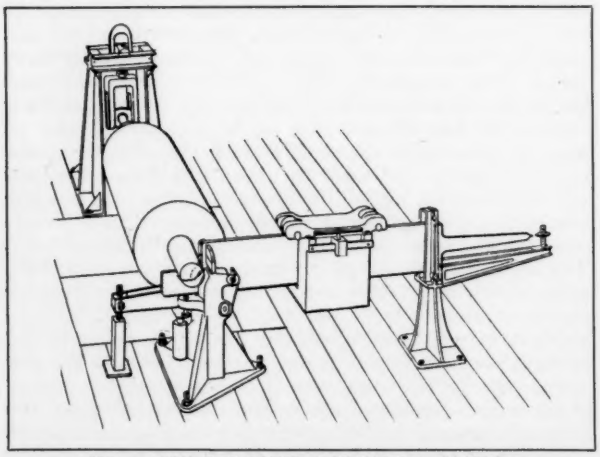

FIG. 1. MARTIN ROTOR BALANCING MACHINE

On all built-up turbines, such as the Zoelly and Curtis types, first the shaft and then each disk put on is successively balanced; the final balance obtained will then be without any disturbing couple, and many times more accurate than any result obtainable by other methods. In a drum-type turbine, such as the Parsons rotor, the overweight is taken out partly at each end in relation to the position of the center of gravity, the sum of this moment being equal to the total moment of overweight. Reduction gear wheels can also be balanced by this machine, and for bodies which are of relatively large radial and small axial dimensions, a mandrel (in itself balanced) to take such parts can be used on the machine. The machine could also be used for standardizing rotary parts. —*The Electrical Review*, Vol. 88, No. 2253, Jan. 28, 1921, pp. 101-102.

HYDRAULIC PROPULSION OF SHIPS

HYDRAULIC or reaction propulsion of vessels whether on air or water is an old idea and has been tried many times, though never successfully so far.

The reaction propulsion has certain advantages, the first

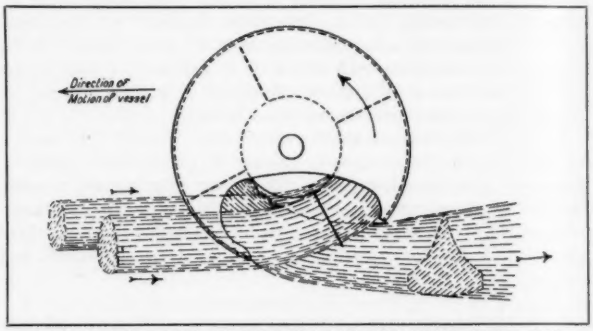

FIG. 2. DIAGRAM OF THE HOTCHKISS PUMP USED FOR REACTION PROPULSION OF SHIPS

of which being the relative simplicity of the propulsive equipment and elimination of the propeller with its appendages, which means not only fewer parts but absence of a rapidly rotating element outside of the ship hull subject to fouling and breakage. The elimination of the propeller leads also to the reduction of vibration. To this is added the ease with which the motion of a hydraulically-propelled boat may be reversed simply by deflecting the stream forward without even reversing the prime mover. This adds to the ease with which the vessel can be maneuvered and makes it possible to eliminate the rudder, another element outside of the ship hull subject to all kinds of untoward accidents.

Finally, the thrust developed by the discharge of the stream of water is independent of the depth at which the stream is discharged, while the depth of immersion of a screw propeller greatly affects the thrust. From these considerations it follows that racing cannot occur in a hydraulically propelled boat. In addition, the depth of water in which the ship operates efficiently is limited solely by the draught of the hull and not by the draught required for the efficient working of the propeller. Among the disadvantages cited against hydraulic propellers the chief is lack of efficiency. Various causes have contributed to the lack of efficiency shown by the systems tried in the past. If we regard hydraulic propulsion as consisting simply of the use of an internal propeller, it is obvious in the first place that loss will occur by virtue of the fact that the stream of water has to be brought to and discharged from the propeller through pipes and passages or orifices of some description. The frictional losses in such passages have no

counterpart in the external propeller, for in this case the water is drawn from and discharged into the immediately surrounding fluid. Again, in reaching and leaving the internal propeller, the water may in its flow be called upon to change its direction of movement to a considerable extent with a consequent considerable loss of energy. The water passages, too, may change in cross-sectional area, and as a result loss will arise by the conversion of pressure into velocity and velocity into pressure.

Lately, however, several reaction propulsion systems have been tried out. The Melot system as applied to aircraft has been described in *The Journal*.

The Hotchkiss and the Gill systems have recently been tried out for watercraft.

The Hotchkiss system was tried on a weldless steel launch measuring 24 feet in length overall and 6 feet 3 inches in beam with a draught of 1 foot 5 inches on a displacement of two tons. The machinery propelling the vessel consisted of an 8-b.hp. motor coupled through reduction beveled gearing to 2 Hotchkiss pumps.

The general principle of the Hotchkiss system is illustrated in the diagram of one of the pumps in Fig. 2. The pump consists of a four-bladed impeller rotating within a cylindrical casing, in which are formed three openings, namely, one in the lower half of each vertical side, and one in the lower portion of the periphery. In the diagram the two strips of the casing separating these three holes are represented as having been cut out, so that the holes really form but one hole. It will be convenient, however, to regard them as being in three. The casing is considerably wider than the impeller blades, so that between the edges of the blades and the vertical walls of the casing there is a passage on each side of considerable area.

In the diagram the movement of the boat is supposed to be toward the left. The impeller is driven in the direction of the arrow shown against it, and creates a vortex inside the casing. The water is drawn into the casing in two streams through the two side holes. Inside the casing these two streams converge, and finally become one, which, passing centrally between the two entering branches, is discharged sternward. The peculiar section which, according to Mr. Hotchkiss, the discharge stream assumes will be noted. It enables the discharge stream to pass between the entering streams without touching them, while at the same time it fills up nearly all the vacant space between them, on the assumption that the entering streams are circular or oval in section.

The essential feature of the Hotchkiss system is thus the creation of a vortex that travels along with the vessel. The water is drawn directly into the vortex without the intermediation of pipes or conduits of any description, and, therefore, frictional losses are practically avoided. The relative momentum of the incoming water, it is claimed, is not lost, but forms part of the momentum of the discharge stream.

The system is still in the experimental stages and no reliable data as to efficiency are available. It is stated, however, that the boat developed 5.6 knots (9.46 ft. per sec.) with the engine running at 950 revolutions and developing 7¾ b.hp. The speed of discharge of the stream from the pumps is calculated by Mr. Hotchkiss to be 16.4 ft. per sec. Calling these two speeds v and V respectively, the slip is $(V - v)/V$, or 42.3 per cent. The jet efficiency is, in accordance with the usual formula, $2v\ (V + v)$, or 73 per cent. Mr. Hotchkiss takes the efficiency of the pumps at 90 per cent, so that the propulsive efficiency comes out at 65.7 per cent. Taking the efficiency of the engine at 75 per cent, the overall efficiency is thus 49.3 per cent. Such an efficiency would not be considered bad in a similar vessel propelled by screw.

These figures have not, however, been checked by any reliable outside authority and are cited merely because of the revival of interest in reaction propulsion.—*The Engineer*, Vol. 131, No. 3398, Feb. 11, 1921, pp. 140-142.

THE TURBINE PATENT FURNACE

DESCRIPTION of a furnace designed on the principle of the impulse turbine. In its construction the air trough corresponds to the nozzle and the fire bars to the blades of the turbine. The air for combustion is forced between the bars which offer but slight resistance and the design is such that each fire bar receives an equal amount of air which is distributed through the narrow air spaces in the form of fine spray. Fig. 3 shows the furnace applied to a Babcock water tube boiler. Its outstanding feature is the dead-plate (7 in the figure) which slopes downward, thus bringing the furnace from 3 inches to 5 inches lower than the ordinary level and giving more room for combustion in the furnace proper. Air is admitted through the chamber as required, through the door fixed under the first bridge. The fire bars are constructed with interlocking lugs so that they cannot be displaced by the rake, and the air spaces slant upward and backward reducing the amount of fine ash or coal that drops through to a minimum. The bottom lugs project forward and intercept the air, thus helping an evenly diffused supply throughout the fire. The grate consists of from four to six furnaces, each receiving its own air supply, which besides insuring an evenly burning fire makes the use of steam jets for creating the draught very simple.—*The Electrical Times*, Vol. 59, No. 1525, Jan. 6, 1921, p. 11.

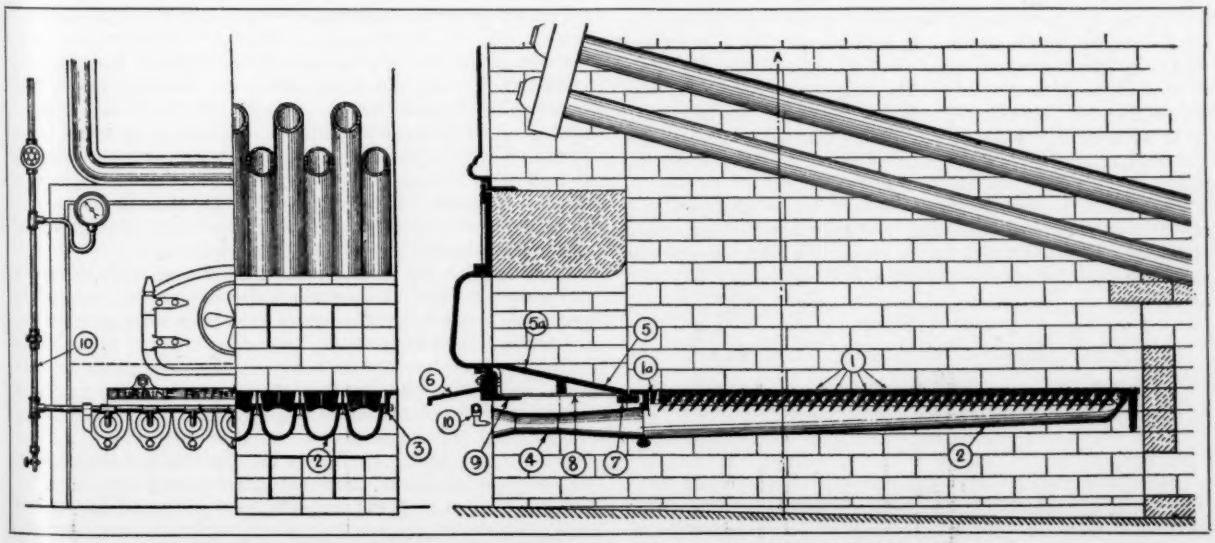

FIG. 3. TURBINE PATENT FURNACE AS APPLIED TO A BABCOCK WATER-TUBE BOILER

LEITNER-WATTS ALL-METAL PROPELLER

IT is stated that all but one of the problems of the metal propeller have been solved in this device, and that one is weight. In their present form these propellers are very much heavier than corresponding wooden screws.

The blades are each made up in the form of a shell of sheet steel and the necessary taper in thickness is obtained by using laminated construction, there being three laminations—one at the top, the second about half way between the tip and the buss, and the third at the root. The laminations are at present riveted together but later on it is intended to employ electric spot welding.

The two halves of each blade are attached to one another at the edges only by welding, but in order to stiffen the shell thus formed small struts are placed between the two faces at intervals.

The method of inserting these struts is shown in Fig. 4. The struts are shouldered at both ends and the hole in one face of the blade is made just the right size to take the thin portion of the strut. In the other face of the blade is cut a hole large enough to accommodate the thick portion of the strut. From this hole runs a slot of a width corresponding to the shouldering portion of the strut. To place in position, the strut is inserted in the large hole, its other end being pushed into the small hole on the opposite face and the shoulder portion is slid into the slot. The strut is then screwed in position by soldering washers over the two strut ends.

The root of the blade is constructed in a rather substantial manner. Balance of the blades is secured by using small balance weights carried on short length of tube secured to the inner end of the central plug in the blade root. These propellers have an adjustable but not a variable pitch, which means that the pitch angle of the blades can be altered over a wide range (10 deg. each way) thus making the propeller suitable for a number of different conditions by setting the pitch according to requirements.—*Aerial Age Weekly*, Vol. 12, No. 22, Feb. 7, 1921, pp. 559-560.

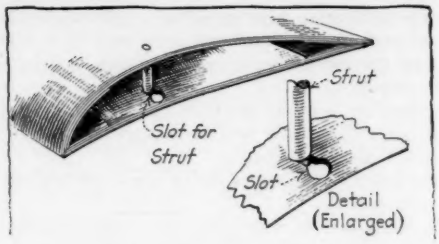

FIG. 4. METHOD OF INSERTING SMALL STRUTS BETWEEN FRONT AND REAR FACES OF THE LEITNER-WATTS ALL-METAL PROPELLER

Progress in Mining and Metallurgy

Abstracts of Papers and Recent Articles

Prepared Under the Auspices of the American Institute of Mining and Metallurgical Engineers

COAL MINING IN SPITZBERGEN

By H. M. CADELL

UNTIL 1920 Spitzbergen was a "No man's land," and although it was claimed as part of the British Empire 300 years ago, the claim had been allowed to lapse, and no other country considered the place worth acquiring. The value was considered to lie in the whaling resources of the region; and, although coal was discovered in 1610, the mineral possibilities of the territory were not seriously considered till the beginning of the present century.

In 1900 a Trondhjem company made an attempt to work the coal that had been found at Advent Bay, a branch of the Ice Fjord, but the financial resources of the concern soon became exhausted, and the claims were bought up, in 1904, for £1,000 by Mr. Longyear, an American, who, under the name of the Arctic Coal Co., of Boston, began to develop the coal field with great energy. It was worked by Mr. Longyear till 1916, when he sold his rights to the present owners, the Store Vorske Kulfelter of Christiania. Others, however, were exploring the ground when the war broke out.

No. 1 mine, worked by Mr. Longyear before 1916 produced about 200,000 tons of coal, and a similar amount was taken out by the present owners before the end of 1919. A piece of the Longyear coal of what seemed average quality analyzed as follows:

	Per Cent
Fixed carbon	57.15
Volatile matter	37.21
Sulfur	0.73
Ash	3.20
Moisture	1.71
Total	100.00

Calories, 7,850 = B.t.u., 14,130.

Heating power (theoretical) (pounds of water at 212° F. evaporated by 1 lb. of coal), 14.54.

Mining and boring operations have proved that the whole ground is frozen to a depth of several hundred feet, and so far none of the Spitzbergen mines has penetrated through the frigid zone, which may be 1,000 feet thick or more. The temperature of the Longyear mines remains uniformly at — 4° C., or about 7° F. below the freezing point of water, and this circumstance has important effects on mining and boring operations, which engineers trained in a temperate climate might never anticipate. In a diamond boring on the Ice Fjord at Klaas Billen Bay, after stopping for a short time, the borers found the hole frozen solid so that the rods could not be withdrawn, and subsequent bores had to be fed with a stream of warm water from a specially devised heater to prevent disaster.

Longwall mining can be carried on without the need for timber to support the roof behind the working face. The frozen roof is wonderfully strong, and the roadways resemble a fairy crystal grotto all crusted with hoar frost. If the roof is scratched, the delicate pendant ice crystals at once drop in a snowy shower. The sides of the roadways through the waste are built up with walls from the stone produced in brushing them, and in the course of time the roof settles down on the building and all is safe.

There is no doubt that there is a great coal field; at places far apart good coal seams extend over a large and accessible area near the sea, besides others that may be won later on, by sinking or working farther inland.

I am not in a position to form any useful estimate of how much coal there may be, but there are certainly two and perhaps more workable seams of good Tertiary and Cretaceous coal, a seam of Jurassic coal of inferior quality, and at least one workable seam of Carboniferous coal, not yet opened out. Mr. Högbom, in 1913,[1] estimated the Tertiary coal with an average thickness of 125 cm. (49 in.) to extend over 1,200

[1] International Geological Congress, *Coal Resources of the World* (1913).

sq. km. (463 sq. mi.), and to amount to 2,000,000,000 metric tons. The total thickness and therefore the quantity is probably much greater than he estimates, since we now know there are at least two workable seams of Tertiary or Cretaceous age extending over large parts of Spitzbergen. The quantity of Carboniferous coal he puts at a still higher figure, but this is a more doubtful estimate.

The advantages of coal mining in Spitzbergen include:

1. The seams of workable coal have been proved to be of high quality as a rule, although of somewhat variable thickness.

2. The field is everywhere very regular and free from faults or dikes, and the dip gentle, so that coal-cutting and conveying plant can be used to save labor and to extract all the coal to the best advantage.

3. The ground being all hard frozen, a strong roof is provided, and little or no timber is required underground.

4. There is no water requiring pumping.

5. The coal outcrops being mostly above or close to the shore, there need at first be no shaft sinking or railway transport to pay for, and ships can be loaded direct from the mine by aerial ropeways worked in many cases by gravitation.

6. Until 1920 there were no royalties, rates, or taxes to pay, and in future these are not likely to become a serious charge on working costs.

7. The climate, although Arctic, is extremely healthy.

Among the disadvantages are:

1. The Arctic winter, when for three months from the middle of November to the middle of February the sun is below the horizon and it is more or less dark, and only three to five months when the coast is clear of ice.

2. The disintegrating effect of the weather on stocks of coal produced in winter for shipment.

3. The possibility of dust in the dry workings.

4. The necessity of importing all supplies, including timber, building materials, food, and machinery.

5. The large excess of exports over imports, making it necessary for most vessels to come light or in ballast to Spitzbergen, and the insurance against risk from ice which tends to make freights relatively higher than in more temperate regions.—Abstract of paper presented before the Mining Institute of Scotland and published in the *Transactions* of the Institute of Mining Engineers.

APPLICATION IN ROLLING OF EFFECTS OF CARBON, PHOSPHORUS, AND MANGANESE ON MECHANICAL PROPERTIES OF STEEL

By Wm. R. Webster

THE former discussion on the physics of steel started with the consideration of five papers presented at the Chicago meeting in 1893, and continued for several years. This paper will be devoted to the practical application, in rolling steel, of the effects of carbon, phosphorus, and manganese on its tensile strength, with some suggestions on further research work.

The variations in the values given by the different investigators for the increase of the tensile strength of steel for each 0.01 per cent of carbon, phosphorus and manganese were largely due to the steels they worked on, the large or small variations in the amount of the elements present, and the omission to take into consideration all the factors, from the blast furnace through to finished rolled material, that affect the character of the steel. For instance, a poorly made steel with the same phosphorus and manganese content requires considerably more carbon than a well-made clean steel to give the same ultimate strength.

None of the values given for each element will apply equally well for all makes of steel or to different works making the same steel. Of course, the development of the quick chemical methods has greatly assisted in this work, especially the quick combustion for carbon determination, which has generally replacd the old color carbons. Fortunately, several of our largest steel manufacturers have always relied on the work of different investigators and coöperated with them. These manufacturers deserve credit for this and for the practical working tables that have been developed and put into daily use at their works. They can now grade their steel and roll it into the finished product with much greater certainty of its meeting all requirements of the standard specifications than formerly, and with much less trouble than when they had to grade the steel from the results of the tension and bending tests of bars rolled from small test ingots from each heat.

When Bessemer steel was in general use for structural purposes, a base of 50,000 lb. per sq. in. was taken, to which 1,000 lb. was added for each 0.01 per cent of carbon contained in the steel. This worked fairly well as a guide, the base being high enough to include the effect of the average manganese and phosphorus contained in the steel, but the results of tension tests of bars rolled from small test ingots necessarily were used for grading the steel. When acid open-hearth steel came into use, the base of 50,000 lb. was found too high.

The importance of this is shown when we consider that there is only a range from about 45,000 to 85,000 lb. in tensile strength of steel used for structural purposes, and that 15 per cent of this 40,000 lb. difference is accounted for by the difference in the results from the same heat of steel when part is rolled into thick and part into thin material.

During the last seven or eight years, some steel works, from their own data and tension tests of rolled material of different weights and thickness on former orders, have made their own tables for rolling similar materials on new orders. The results are most satisfactory, as the makers have at once the data required to grade and roll heats of steel best suited to comply with the requirements of each order. These tables cover not only the thickness of the steel but all other rolling conditions at the particular mill for which the table is designed. Formerly, it would have been almost impossible to collect such data, owing to the large number of specifications in general use. It was through the work of the Steel Committee of the American Society for Testing Materials that steel specifications were standardized and many of the old specifications scrapped. The other engineering societies coöperated in this work, and the whole range of structural steel is now covered by about six subdivisions, the limits of each covering a range of about 10,000 lb. in tensile strength. Some of these overlap, as for instance, 55,000 to 65,000 lb. per sq. in. overlaps the 50,000 to 60,000 lb. and 60,000 to 70,000 lb. These standard specifications simplified matters very much.

In mill work, when grading good basic open-hearth steel, there is little need of considering the differences in the effects assigned to the unit of phosphorus, as the phosphorus in this steel does not generally vary more than four points, while the additions to the tensile strength, when estimated by the different methods referred to, varies from about 1,500 to 3,000 lb. per sq. in. Most of this is generally covered by the differences in the values given to the effects of manganese and carbon. Satisfactory results are obtained in rolling steel under all of these varying methods. There has always been a great difference in the opinions of investigators and manufacturers of steel regarding the effect of manganese on its tensile strength. Some claim that the effect was slight, others that there was no effect on basic open-hearth steel until the manganese was above 0.40 or 0.60 per cent., but most of them admit its effect on acid open-hearth steel.—*Mining and Metallurgy*, March, 1921.

THACHER MOLDING PROCESS FOR PROPELLER BLADES

By Enriqwe Touceda

FOR a number of years prior to the World War, the firm of Geo. H. Thacher & Co., of Albany, N. Y., was engaged in the manufacture of marine and other gray-iron castings. At the outbreak of the war the firm decided to specialize in the manufacture of propeller wheels. It attacked the problem therefore from a foundry point of view, seeking to produce a

propeller casting that would be so accurate that no subsequent machining would be required on the blades.

There were two general methods of manufacture, the shortcomings of which have been freely acknowledged. In the sweep method, the nowel, or bottom half-mold, for each blade is swept up by a spindle beam and pitch race, while the top half-mold for each blade is built up individually. In the pattern method one individual blade, with the hub or hub portion, is mounted on a spindle and the individual blade mold formed; the pattern is then rotated on the spindle to the position for the next blade, etc. Only in rare cases were wheels made from a solid pattern, owing to the cost of the pattern, its failure in many instances to be correctly made, and (when made of wood) its early and sure distorting. Metal patterns in most instances were prohibitive in cost. In these methods green-sand and loam molding was practiced. The casting produced by either method can be considered only as a blank from which the propeller must be machined. The back surface of each blade must be chipped to the templet and then chipped to such accuracy as will be required for a static balance. Inasmuch as the work done by the machine tool is confined to the driving face of the blades, not only is perfection most difficult, but corrosion will be greater because of the removal of the dense skin of the casting and the local strains set up by the pneumatic tool in chipping.

To produce a finished 9-ft. propeller for a Navy destroyer required from 8 to 21 days of foundry work and about the same length of time for the machining. Through the use of the Thacher process, only as many hours are required; besides, it is possible to produce a finished casting in perfect conformity with any particular propeller-wheel design. The method is fool proof against inaccuracy for each part of the mold is contained within and supported by a cast-iron casing, or container, the dowel pins of which are fashioned to engage accurately the holes in the casing, or bedplate to which it is to be attached. So accurately made are the various parts of the cast-iron flask that in the case of flask and mold equipments covering certain limiting diameters and pitches of wheel, any part of one outfit is interchangeable with the same part of any other similar outfit. A perfect propeller wheel was cast from a completely assembled mold made up in Albany that was shipped, uncrated, by ordinary freight to a foundry just outside of Boston.—Abstract of paper to be read at the Wilkes-Barre Meeting, September, 1921.

Correspondence

The editor is not responsible for statements made in the correspondence column. Anonymous communications cannot be considered, but the names of correspondents will be withheld when so desired.

SUPPRESSION OF TEETH OF RUMINANTS

To the Editor of the SCIENTIFIC AMERICAN MONTHLY:

LITTLE is known about the suppression of the teeth of Ruminants. It is however thought they at one time had full dentition. The variation in cows' teeth given here furnishes interesting speculation on the subject.

The specimen (Fig. 2) is the skull of a Jersey cow owned by George Elkins, Rogersville, Tenn. The tooth was discovered on the death of the cow and extracted by the writer, thinking at the time that it was merely a curiosity. The tooth was worn by a neighbor as a watch fob and lost. It was one inch long, having the normal shape of a lower front and articulated perfectly with the right lower front. The cow had a normal number (8) of lower front teeth. No other variation was noted. The cow had a progeny of four, none of which showed any variation. This appears on investigation to be the only case of the kind ever reported.

The absence of upper front teeth is a general characteristic of ruminants, yet rudimentary canines exist in some deer. Cuvier first pointed out that there was a relation between the presence of horns and the absence of canine teeth, the latter serving as weapons of sexual combat solely, while those with fully developed horns had no use for such weapons of offense.

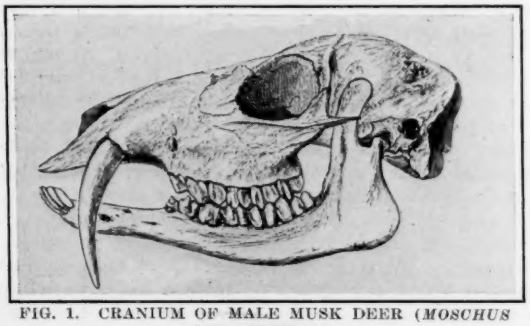

FIG. 1. CRANIUM OF MALE MUSK DEER (*MOSCHUS MOSCHIFERUS*)

From Jones Dental Anatomy

FIG. 2. SKULL OF COW WITH CAVITY, SHOWING AN UPPER FRONT TOOTH

According to Sir Victor Brooke: "The upper canines are present in both sexes in all the species of Cervidoe, with the exception of Alces, Rangifer, Dama and some smaller species. . . . The upper canines when present are, with the notable exception of Moschus, Elaphodus, Cervulus and Hydropotes, small latterally compressed rudimentary teeth. Their crowns are in about the same stage of reduction as the crowns of horses' canines, but their roots are relatively much more reduced."

The hornless musk deer (*Moschus*) possess upper canines of most formidable dimensions, while the female has very small subcylindrical canines.

The Indian Muntjac deer (*Cervulus*) has somewhat small horns, which are perched upon persistent bony pedicles, and it has upper canines which are curved outward from beneath the upper lip, much as are the tusks of a boar.

The theory was formerly advanced that uncalcified tooth germs were to be found in the foetuses of many species of the cow and sheep. This is now denied by almost all modern investigators. However, Miss Mayo (*Bull Comp. Zoöl. Harvard*, 1888), advances the idea that the suppression of the teeth has been progressive. She points out that in the region of the missing canine differentiation proceeds a little further than in the incisor region, though it never reached the stage of a real tooth germ. This supposition would mean that the incisors were lost at one period of evolution and the canines at a much later period.

M. V. KOGER.

Rogersville, Tenn.

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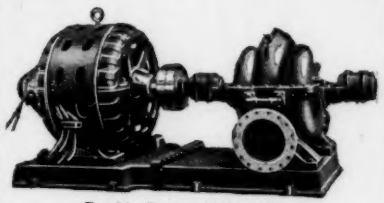
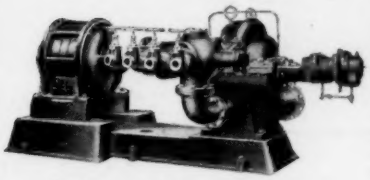


Double Suction Volute Pump



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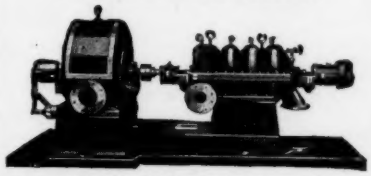

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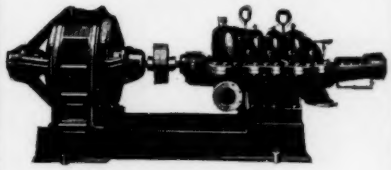
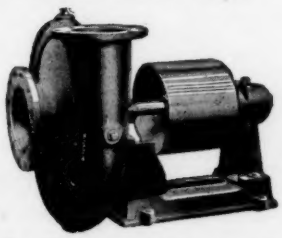


Multistage Centrifugal Pump



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